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BIOGRAPHICAL MEMOIRS

VOL. XIX

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Robert S. Woodward

NATIONAL ACADEMY OF SCIENCES
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BIOGRAPHICAL MEMOIRS
VOLUME XIX—FIRST MEMOIR

BIOGRAPHICAL MEMOIR

OF

ROBERT SIMPSON WOODWARD

1849–1924

BY

F. E. WRIGHT

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1937

ROBERT SIMPSON WOODWARD[1]

1849–1924

BY F. E. WRIGHT

A thorough knowledge of mathematics and physics is an excellent introduction to creative work in astronomy, geology, and engineering. In the early days of the National Academy of Sciences this close connection between mathematics and physics, on the one hand, and astronomy, geology, and engineering, on the other, was recognized in the names of the Sections to which Academy members were assigned. Thus Dr. Woodward belonged for many years to the Section of Mathematics and Astronomy and to the Section of Physics and Engineering. He was one of a group of investigators whose interest was primarily in mathematical physics; but who, in his own words, realized that "the earth furnishes us with a most attractive store of real problems"; that "its shape, its size, its mass, its precession and rotation, its internal heat, its earthquakes and volcanoes, and its origin and destiny are to be classed with the leading questions for astronomical and mathematical research." To these problems men like Laplace, Fourier, Gauss, G. H. Darwin, and Lord Kelvin devoted much attention, and in so doing advanced both geology and astronomy and their own mathematical physical sciences.

Dr. Woodward's contributions to geology were in the domain of geophysics, and, although his articles were printed many years ago, they still rank as the most important papers on these subjects thus far published in America. His influence, moreover, in stimulating and encouraging geological work and, in his later years, as president of the Carnegie Institution of Washington, in organizing and administering research projects in geophysics and astrophysics has been an important factor in the progress of geology, astronomy, and other sciences.

Robert Simpson Woodward was born on July 21, 1849, at Rochester, Michigan; he died on June 29, 1924, at Washington,

[1] Revision of "Memorial of Robert Simpson Woodward," by Fred. E. Wright, published in the Bulletin of the Geological Society of America, Vol. 37, pp. 115-134, 1926.

D. C., at the age of nearly seventy-five years, after a long period of illness and suffering, following an attack of influenza.

His early life was spent on a farm near Rochester, a village in Oakland County about 30 miles north of Detroit. His father, the Hon. Lysander Woodward, was one of the most progressive farmers in the State; he sought to apply scientific principles to the operation of his farm and took a keen interest in public affairs. Farm land in this part of the State is of excellent quality and responds well to proper treatment. Without question, this attitude of mind of the father was passed on to the son, who ever afterward was an enthusiastic student of farming methods and in later years acquired and successfully operated, for recreation, a farm in Montgomery County, Maryland, not far from Washington. The following biographical sketch of his father, given in C. R. Tuttle's General History of the State of Michigan, Detroit, 1873, pages 167-168, is significant:

"Lysander Woodward, one of the most prominent men in Oakland County, was born in the town of Columbia, Tolland County, Connecticut, November 19, 1817. His parents, Asahel Woodward and Harriet House, were natives of that State. In 1825, with his parents, he removed to the town of Chili, Monroe County, New York. From here he emigrated to Michigan in the fall of 1838. He married Miss Peninah A. Simpson on the 11th of May, 1843, and settled near the village of Rochester, Oakland County, Michigan, where he still resides. Mr. Woodward's chief occupation is that of a farmer, but he has held many important offices in his township. In 1860 he was elected representative from the first district of Oakland County to the State Legislature, and served with considerable distinction during one regular and two extra sessions. He was county treasurer of Oakland County two terms and performed his duties in a thoroughly satisfactory manner. Mr. Woodward was also president of the Oakland County Agricultural Society for three years, and in this position did great service in advancing the agricultural interests of the Detroit and Bay City Railroad and has been instrumental in canvassing for and promoting its construction. He was chosen the first president of this company in 1871, which important office he held up to May 15, 1873, and he still remains one of the directors of the company. Mr. Woodward owns one of the largest and best cultivated farms in Oakland County."

Doctor Woodward's mother belonged to the Simpson family, a name prominent in the annals of Connecticut. From his mother he inherited many genial traits of character and an interest in

his fellow-man, traits that were an integral part of his personality.

His boyhood days were passed in an atmosphere of pioneer farm development, coupled with a broad interest in public affairs. His school training was excellent. The Rochester Academy which he attended ranked well among the schools of the State, and his teachers, especially one, were better than the average. On finishing the academy he wished to go to the university, but his father was not in sympathy with university training and only after the most earnest appeals was he persuaded to allow his son to attend. Four years later, in 1872, the son graduated from the University of Michigan with the C. E. degree. Several summers during the college period were spent in field-work as aide on the United States Lake Survey. After graduation he became assistant engineer on the United States Lake Survey and retained this position for ten years, until 1882, when the work was practically finished.

During this period he was engaged chiefly in primary triangulation work on the Great Lakes, under the leadership of General Comstock of the Corps of Engineers, War Department. This gave him a most thorough training in primary triangulation, in latitude and longitude determinative work, in the testing of field instruments and field methods, and in the office adjustment of field observations by least-square methods. The results of this work were published in chapters 16 to 20 and 24 and 25 of General Comstock's Monographic Report on the Survey of the Lakes, Professional Paper No. 24 of the U. S. Army Engineers; also in several articles in technical journals. During this period Dr. Woodward acquired an interest in the earth as a whole—in its shape, its tides, its atmosphere, and in the host of geophysical problems, many of which still await solution. This keen interest was maintained throughout his life and led him during the next decade to investigate some of the outstanding geophysical problems, and to solve them in spite of formidable mathematical difficulties. To him they had an irresistible fascination, and in later years he looked eagerly forward to the time when he could lay aside administrative duties and return to his research work in geophysics.

On leaving the Lake Survey Dr. Woodward joined the United States Transit of Venus Commission as assistant astronomer and was associated with it for two years, 1882 to 1884, with Professors Asaph Hall and William Harkness. During the transit of 1882 he was with the observing field party under Professor Hall at San Antonio, Texas. There were eight field parties, four in the United States and four in foreign countries, and each party took a number of photographs during the transit of Venus across the sun's disk. These photographs were deposited with the Naval Observatory, where they were carefully measured, and the data of measurement were used in computations to obtain a more nearly correct value of parallax than had hitherto been possible. An immense amount of labor was put into this task, but, as a result of improvements in methods along other lines, the parallax values thus derived were superseded before the final report was completed and it was accordingly not issued.

The twelve years thus spent by Dr. Woodward in geodetic and astronomic work of the highest precision, but always with an immediate practical bearing, trained him to an engineer's sense of values and proportion. Whenever a problem arose he instinctively sought not only the means of solving it, but also the most direct method that would give results of the desired degree of accuracy with the least expenditure of energy. We shall now see how in the next decade he utilized this training to the utmost and made to geology and geodesy remarkable contributions that would otherwise have been impossible. This same resourceful attitude of mind also makes for success in administrative work. It was inevitable, therefore, that in later years Dr. Woodward's balanced judgment should be sought on all sorts of technical and scientific problems, and that he should be drawn eventually into executive work.

From the Naval Observatory Dr. Woodward was called in 1884 to the United States Geological Survey as astronomer, where he soon became geographer, and then chief geographer in charge of the Division of Mathematics. The Geological Survey was at this time still young and had much to learn in all its branches; but its members were men—like Gilbert, Dutton,

King, and Chamberlin—who, as masters in geology, with a virgin country to investigate, were full of enthusiasm and eager to accomplish much. It was a congenial atmosphere to enter, and during the next six years Dr. Woodward wrote his most important scientific papers.

His tasks on the Geological Survey were of two kinds, namely, those arising from the topographic branch in connection with field methods and map-work, and the investigation of problems of a geologic nature, but involving the behavior of the earth as a whole. To the first group of tasks Dr. Woodward had long been accustomed. They included latitude and longitude determinations at critical stations in different States, problems on map projection, and the testing of field methods. He prepared a set of formulas and tables to facilitate the construction and use of maps. These tables, in amplified form, are still in use at the Geological Survey and constitute the basis for its topographic sheets. He prepared sets of instructions on methods best adapted for field use in primary and secondary triangulation. With the aid of several members of his division, he set up a small observatory for use in testing field instruments and in giving instruction to topographers in field topographic methods, especially latitude and longitude determinations. As a result of this work, the field methods were put on a practical engineering basis, thus securing the desired degree of accuracy with the minimum expenditure of funds and energy.

Geology at this time was moving forward rapidly, and the geologists of the Survey naturally turned to Dr. Woodward for assistance in problems of a mathematical physical nature. G. K. Gilbert found, for example, that within the area covered originally by Lake Bonneville the shoreline observed on an island in the central part of the lake was 129 feet higher than the strandline at its margin. The question arose, Was this difference in elevation due to the disappearance of the water? T. C. Chamberlin wished also to know to what extent the form and position of the sealevel may have been modified by the attraction of the Pleistocene ice-cap. A general solution to these two problems was given by Dr. Woodward in Bulletin of the U. S. Geological Survey No. 48 on the "Form and position of sea-

level, with special reference to its dependence on superficial masses symmetrically disposed about a normal to the earth's surface." This problem was one requiring for its solution mathematical work of the highest order and, in addition, the experience of the engineer, so to shape his formulas that they could be applied directly by the computer. The problem, as Dr. Woodward attacked it, became that of the deformation of the terrestrial geoid (as expressed by the surface of the sea) by the attraction of an ice-cap or other mass. It meant the investigation, by means of the potential theory, of the change in the equipotential surface of a large lake or sea as a result of the presence of an ice-cap, or of a body of water, or of a continental mass. The new set of formulas developed by this investigation sufficed to answer not only the questions of Gilbert and Chamberlin, but also other related questions concerning the distribution of density in the earth's mass and regarding the effect of continental masses on sealevel. In an historical note appended to this paper, Dr. Woodward analyzes the work of Croll, Archdeacon Pratt, D. D. Heath, and Sir William Thomson on this subject and shows the scope of each treatment. The work of these mathematicians demonstrated clearly the limitations that arise when the analyst is satisfied with a general solution to a problem, but fails to obtain a solution that is suitable for computation purposes. On this point Dr. Woodward insisted repeatedly. Thus, in his papers on the free cooling and on the conditioned cooling of a homogeneous sphere, he "sought to express the solutions in such terms that the computer can, without undue labor, assign the temperature at any point within the sphere for any value of the time, having in mind always an application of the theory to the earth." Again, in his paper on the diffusion of heat in a homogeneous rectangular mass, he refers to the extraordinary studies of Fourier and Poisson and notes that "we must extend their work and adapt it to the practical needs of the computer."

Other problems were referred to Dr. Woodward while he remained with the Geological Survey. Thus Mr. Gilbert, in the course of his studies on the moon's face, wished to ascertain the average angle of incidence of meteors and moonlets impinging on the moon. Mr. Gilbert favored the meteor impact theory for

the formation of the moon's craters and sought an explanation for the absence of elliptically shaped craters, which one might expect to find if the meteorites struck the moon at angles other than about normal to its surface. Dr. Woodward solved the general problem of the frequency of the different angles of incidence and showed how they vary with the assumptions made.

For the Division of Chemistry he studied the ratios of the weights of the chemical elements and made least-square adjustments involving the solution of 30 simultaneous equations.

From the geologist's viewpoint, Dr. Woodward's most important contributions of this period are his papers on the free and conditioned cooling of a homogeneous sphere and his application of the results presented therein to the secular cooling of the earth and to its age. Geological thought with respect to the age of the earth had been dominated for a generation by the conclusions of Lord Kelvin, who in 1862 and again in 1883 stated, after a detailed mathematical investigation of the subject, "We must allow very wide limits in such an estimate as I have attempted to make; but I think we may with much probability say that the consolidation can not have taken place less than 20,000,000 years ago, or we should have more underground heat than we actually have, nor more than 400,000,000 years ago, or we should not have so much as the least observed underground increment of temperature; that is to say, that Leibnitz's epoch of emergence of the *consistentior status* was probably between those dates." Geologists accepted this statement by Lord Kelvin because his arguments, so far as they could follow them, seemed sound. Nevertheless, although they could not refute his statements, they found it difficult to reconcile them with a mass of geological evidence. Dr. Woodward undertook to reexamine the entire problem, and carried the solution much further than had Lord Kelvin or his predecessors.

The problem of a cooling sphere was not new.

"It was very thoroughly discussed in its purely mathematical features by Fourier and Poisson, the pioneers in the theory of heat, and has been much studied by mathematicians of later date. Able and elaborate as their work is, however, it is not well adapted to the needs of practical application; it does not enable one to trace readily and accurately all the phe-

nomena of cooling throughout their entire history. My investigations of this problem were necessarily made partly with a view to supplying the defect just named."

In his paper Dr. Woodward gives the data necessary for calculation of the secular cooling of the earth; the age of the earth derivable from such data; the distribution of the isogeotherms; the rate of increase of underground temperature and its variation with the time; the radial and volume contraction; the stratum of no strain.

He summarized his conclusions in an address in 1889 as vice-president of the Section of Mathematics and Astronomy of the American Association for the Advancement of Science. After presenting an excellent digest of the work of his predecessors, Dr. Woodward remarks that the conclusions of Lord Kelvin are very important if true.

"But what are the probabilities? Having been at some pains to look into this matter, I feel bound to state that, although the hypothesis appears to be the best which can be formulated at present, the odds are against its correctness. Its weak links are the unverified assumptions of an initial uniform temperature and a constant diffusivity. Very likely these are approximations, but of what order we can not decide. Furthermore, if we accept the hypothesis, the odds appear to be against the present attainment of trustworthy numerical results, since the data for calculations, obtained mostly from observations on continental areas, are far too meager to give satisfactory average values for the entire mass of the earth. In short, this phase of the case seems to stand where it did twenty years ago, when Huxley warned us that the perfection of our mathematical mill is no guaranty of the quality of the grist, adding that as the grandest mill will not extract wheat flour from peas-cods, so pages of formulæ will not get a definite result from loose data."

This statement by Dr. Woodward, together with his published re-treatment of the entire problem, set the minds of geologists at rest concerning the restrictions imposed by Lord Kelvin. Some years later the generation of heat by transformations in radioactive substances within the earth's crust was discovered as a factor tending to retard the rate of cooling of the earth and to increase the limits set by Lord Kelvin.

In this same vice-presidential address Dr. Woodward summarized also the opinions regarding the contractional theory of

the earth and the theory of isostasy which had been propounded only a few months before by Dutton, and he inferred "that isostasy is competent only on the supposition that it is kept in action by some other cause tending constantly to disturb the equilibrium which would otherwise result. Such a cause is found in secular contraction and it is not improbable that these two seemingly divergent theories are really supplementary." With reference to the solidity or the liquidity of the earth's interior he notes that "the difficulties appear to be due principally to our profound ignorance of the properties of matter subject to the joint action of great pressure and great heat. It is not clear how our knowledge is to be improved without resort to experiments of a scale in some degree comparable with the facts to be explained." Dr. Woodward was a firm believer in experiment. In his own words, "The price of progress, like that of liberty, is eternal vigilance. One must be ever active, ever patiently persistent, proving all things and holding fast to that which is good."

Dr. Woodward was also interested in the possible laws of arrangement of density in the earth's mass under the assumption that the density increases continually from the surface toward the center. Realizing the dependence of the arrangement of density on certain known properties of the earth, such as its mean density, its surface shape and surface density, and its constant of precession, he sought to determine the most probable law of increase, but found that the available data were not adequate for the purpose.

In 1890 Dr. Woodward resigned from the Geological Survey to accept a position with the United States Coast and Geodetic Survey. Major J. W. Powell, in his Report of the Director of the Geological Survey for 1889-1890, states that Dr. Woodward's "resignation was accepted with regret, as this Survey can ill afford to lose his rare ability for mathematical research. Since his first association with the Survey, in 1884, he has not only supervised the computations made in connection with the triangulation and astronomic determinations, conducted the computation of a series of tables for the use of the Topographic Branch, and given aid to geologists having occasion to read their data by mathematical methods, but he also made important additions to

geologic science by discussing and advancing, on several lines, the theories of terrestrial physics. His discussion of the form and position of sealevel of the earth as dependent on superficial distribution of matter yielded formulas and numerical results of importance in the discussion of the physical results of the filling and emptying of the Bonneville Basin, of the formation and dissolution of the northern ice-sheet, and of all other phenomena involving the influence of superficial masses on the geoid. His discussion of the problem of a heated sphere, such as is presented by the earth, and of the contraction resulting from its slow cooling, is especially valuable for its indication of the additional work needed for the determination of the constants involved, and for the illustration of the dependence of the mathematical results upon important postulates, the possibility of whose future demonstration is not apparent. He has also studied and discussed the distribution of density and pressure within the earth and made a preliminary study of the stresses and strains involved in the deformation of the earth's crust within the limits of elasticity."

Dr. Woodward was called upon by the Coast and Geodetic Survey, because of his long experience in precise triangulation, "to devise means of testing in the most thorough way practicable the efficiency of the various forms of base apparatus used by the Survey, especially the efficiency of long steel tapes or wires." To this congenial task he applied himself with pleasure and enthusiasm. He devised the iced bar apparatus for measuring base lines and for calibrating steel tapes. His method for calibrating steel tapes was adopted by the Coast and Geodetic Survey and remains still the standard method. He was also the first to measure primary base lines with long steel tapes, and to prove that these tapes furnish the required degree of accuracy, namely, one part in one million. This work was of fundamental importance to geodesy and not only resulted in the saving of much money and time in field-work, but placed the primary triangulation work of the Coast and Geodetic Survey on a higher plane than had been theretofore possible. He insisted, moreover, that, in the field, measurements only of the kind and number be taken that are necessary to insure the desired degree of

accuracy. His influence led Hayford some years later to revise and standardize the field and computational methods of the Coast and Geodetic Survey, thereby greatly increasing the speed of the work, lowering the costs, and placing the results on a uniformly high level of known precision. In this respect the Coast and Geodetic Survey set the example for other surveys the world over.

Maps constitute a very important item in geology, and for this contribution alone geology owes much to Dr. Woodward.

While at the Coast and Geodetic Survey Dr. Woodward prepared for the Smithsonian Institution the Smithsonian Geographical Tables. In the introductory part (93 pages) of this volume useful formulas are given for the geographer and cartographer, the geodesist and astronomer; also a brief statement of the theory of errors is included. The tables cover 180 pages and furnish data of interest to geographers and students of allied sciences. The third edition of these successful Tables was issued in 1906 and was reprinted in 1918.

In 1893 Dr. Woodward was called to Columbia University as Professor of Mechanics and Mathematical Physics. From that time on, his work was that of the teacher and administrator. In 1895 he became dean of the College of Pure Science and was confronted with many problems that required tact and perseverance for their solution. His influence on the student body and on the students directly under him at Columbia was remarkable. He insisted on good work from each student, but he was ever ready to give help where it was needed. His thorough knowledge of mechanics and of the needs of the engineer enabled him to give to his engineering students the kind of information they most needed, and to train them to the attitude of mind essential to successful accomplishment in engineering work.

Intensely interested in the human element, and with a most attractive, genial, and lovable personality, his advice was sought on every side, both by the student body and by the faculty; so that, in spite of the best intentions and very hard work, he could not obtain for himself the desired periods of quiet to pursue his mathematical work, to which he looked ever forward.

He did, however, undertake, with the aid of Professor Wills and Dr. Deimel, an investigation into the possibilities of the double suspension pendulum for the determination of the value of gravity. The advantage of this method over the ordinary method is the ease with which the length of the pendulum can be ascertained; its disadvantage is the uncertainty regarding the elastic behavior of the suspension fibers or ribbons. Dr. Woodward made a thorough mathematical investigation into the subject, but was called to another position before the experimental work had been completed, and he never found an opportunity to finish the task. The records of the investigation, so far as they were carried, are on file in the Physics Department of Columbia University.

His interest was also aroused by A. L. Queneau in the cooling and crystallization of intrusive igneous masses as an example of a special case of the general theory of the cooling of a heated mass (bar or sphere), as developed by Woodward in 1888. Dr. A. C. Lane was the first to treat this problem, but his solution was somewhat different from that of Dr. Woodward. Queneau adopted Woodward's mode of treatment and applied it to a study of certain igneous rocks, arriving at essentially the conclusions reached by Dr. Lane.

On December 13, 1904, Dr. Woodward became president of the Carnegie Institution of Washington, and met the problems of this new kind of research institution with the same good common sense that characterized all his executive work. He analyzed each problem thoroughly, including that of personnel, and insisted that the institution be run on a thoroughly business-like basis, that it live within its income, and that its money be spent with fair expectation of a good return. He established several departments of the institution and organized the institution about them. Miscellaneous appropriations to aid individual pieces of research were carefully scrutinized and every effort was made to spend the money entrusted to his care wisely and in the interests of science. Dr. Woodward showed keen appreciation of scientific activities outside his own sphere of astronomy and earth science and in his later years was much interested in archæology and in the humanities generally.

He believed that he who thinks clearly writes clearly. "It is so much easier to appear to write well, or even brilliantly, than it is to think clearly, that facile expression is often mistaken for sound thought." He himself wrote exceedingly well and coined many apt and telling phrases.

In his relations with the men of the institution under him he showed the keenest interest and encouraged them wherever possible. His home life was of the ideal kind. Both he and Mrs. Woodward had a genius for hospitality and made each visitor feel at ease. Their home in Washington was ever the meeting place for scientific and other folk, just as it had been at Columbia University.

In the early days of the Carnegie Institution the effort to find and to aid the unusually talented man in his scientific work, in accordance with the expressed wish of the founder, Mr. Carnegie, led to the placing of numerous small grants with men over the country who had special problems to solve. When Dr. Woodward became president he examined carefully into these random grants and found that a surprisingly small number yielded returns to science commensurate with the outlay. He therefore concluded that, so far as possible, the efforts of the Carnegie Institution should be concentrated on projects of large scope, which would probably not otherwise be attempted, and that these efforts for the most part should be carried forward by investigators in the employ of the Institution. The result was greater emphasis on the departments of the Carnegie Institution, such as the Geophysical Laboratory and the Mount Wilson Observatory, and the more intensive development of all these departments. A few research associates who were able to give their entire time to special research problems were also maintained as integral members of the Institution, but the voting of small grants to aid in the solution of specific problems under attack by individuals connected with other institutions was minimized as a policy of the Institution.

At the outbreak of the war Dr. Woodward was much disturbed by the trend of events in Europe, and, when this country entered the war, he was influential in persuading the trustees to offer the services of the entire Institution to the Government.

The war work of the Carnegie Institution covered many fields of activity, from the manufacture of optical glass to military intelligence work, and to it all Dr. Woodward offered the most effective support. He himself was a member of the Naval Consulting Board, as one of the two representatives from the American Mathematical Society to the board.

Dr. Woodward was president of the Carnegie Institution from December 13, 1904, to January 1, 1921, a period of sixteen years. The first president of the Institution, Dr. D. C. Gilman, president emeritus of Johns Hopkins University, had retired from active life, and he undertook the task only temporarily, until the best man for the position could be selected. When Dr. Woodward entered upon his duties the Institution was two years old and had still to establish itself in the minds of the public and to determine on the best policies to follow. It needed at this critical period the mature judgment and experience that Dr. Woodward had acquired in governmental and educational positions; it needed also an enthusiastic and genial personality to carry through successfully the projects that merited encouragement and at the same time to avoid the far greater number of suggested projects which, although urged upon the Carnegie Institution most insistently, really promised little return. On looking back over his years of activity, he states in his last report as president that "probably no other organization in the evolution of learning has been so beset by what Dr. Johnson called the anfractuosities of the human mind as the Carnegie Institution of Washington." But his keen sense of humor carried him over the rough places and his kindly, well-balanced attitude instilled in those with whom he came in contact the feeling of assurance that each proposal would be dealt with fairly and on its merits. Thus it was that the Carnegie Institution grew and flourished and contributed much to the development of science in this country.

Dr. Woodward received many honors from different scientific societies. He was vice-president of the Section of Mathematics and Astronomy of the American Association for the Advancement of Science, in 1889; its treasurer, 1894-1924, and its president in 1900; president of the American Mathematical Society,

1898-1900; of the New York Academy of Sciences, 1900-1902; of the Washington Academy of Sciences, 1915; of the Philosophical Society of Washington, 1910, and of the Literary Society of Washington, 1913-1914. He was a member of the National Academy of Sciences, the Astronomical Society, and the American Physical Society, and fellow of the American Academy of Arts and Sciences and of the American Philosophical Society. He was elected a member of the National Academy of Sciences in 1896. He served as member of its Council from 1909 to 1915 and on the following Academy committees: Weights, Measures, and Coinage (1906-1924); Gould Fund (1915-1924). He was Chairman of the Section of Physics and Engineering (1908-1913); and Chairman of the Special Committee appointed in 1913 to advise the Secretary of Agriculture on the selection of a new Chief for the United States Weather Bureau. He was a member of the Executive Board of the National Research Council, 1918-1920; of the Executive Committee of its Division of Physics, Mathematics, Astronomy, and Geophysics, 1918-1920; and of the Section of Geodesy, of the American Geophysical Union, 1919-1920.

He was associate editor of *Science* from 1884 to 1924, and of the *Annals of Mathematics* from 1888 to 1889. Together with Prof. Mansfield Merriman, he edited a series of mathematical monographs; he himself contributed in 1896 to the series the monograph on the "Theory of Probabilities."

From the universities he received many honorary degrees: University of Michigan, Ph. D. in 1892; LL. D. in 1912; University of Wisconsin, LL. D. in 1904; University of Pennsylvania, Sc. D. in 1905; Columbia, Sc. D. in 1905; Johns Hopkins, LL. D. in 1915. He was a member of the Century Association of New York and of the Cosmos Club in Washington.

In 1876 he married Miss Martha Gretton Bond of Detroit who with three sons survived him.

In addition to his great attainments, Dr. Woodward possessed a simplicity and open friendliness of manner and character that endeared him to young and old alike. It was a privilege to know him, to feel his radiant enthusiasm, and to be uplifted by his hopeful outlook on this world and its many problems.

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BIBLIOGRAPHY

1875

Determination of the errors of graduation of Troughton and Simms theodolite number 2. Appendix E, U. S. Lake Sur. Rept., 1875, 5 pp.

1879

Constants of Troughton and Simms theodolite number 3. Appendix 7, U. S. Lake Surv. Rept., 1879, 7 pp.

1882

Primary triangulation of the United States Lake Survey. Prof. Papers, Corps Eng., U. S. Army, no. 24, chapters XVI to XX, XXIV to XXV, 288 pp.

On the actual and probable errors of interpolated values from numerical tables by means of first differences. The Analyst, vol. 9, pp. 143-149, 169-175.

1883

Results of experiments to determine the variations in length of certain bars at the temperature of melting ice. (With E. S. Wheeler, A. R. Flint, and W. Voigt.) Amer. Jour. Sci., third series, vol. 38, pp. 337-355. Abstract of this paper appeared in Zeitschrift für Instrumentenkunde, Band 3, pp. 322-324, under the title Aenderung der Länge verschiedener Stäbe bei derselben Temperatur.

Special treatment of certain forms of observation equations. Abstract in Bull. Phil. Soc. Wash., vol. 6, p. 156.

1884

Note on the optical formula expressing the relation of conjugate distances, and on the theory of the stadia. Van Nostrand's Eng. Mag., vol. 30, pp. 473-476.

Discussion of a concrete problem in hydrostatics proposed by Mr. G. K. Gilbert. Title. Bull. Phil. Soc. Wash., vol. 7, p. 101.

1885

Some practical features of a field time determination with a meridian transit. Bull. Phil. Soc. Wash., vol. 8, pp. 55-58.

On variations of latitude. Abstract in Bull. Phil. Soc. Wash., vol. 8, p. 10.

1886

On errors incident to interpolated values from numerical tables. Ann. Math., vol. 2, pp. 54-59.

On the rate of recession of Niagara Falls, as shown by results of a recent survey. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 35, p. 222.

On the position and shape of the geoid as dependent on local masses. Title. Bull. Phil. Soc. Wash., vol. 9, pp. 570-571.

Is the ocean surface depressed? Science, vol. 7, pp. 570-571.

On the form and position of the sealevel as dependent on superficial masses symmetrically disposed with respect to a radius of the earth's surface. Ann. Math., vol. 2, pp. 97-103, 121-131; vol. 3, 1887, pp. 11-26.

1887

On the free cooling of a homogeneous sphere. Title. Bull. Phil. Soc. Wash., vol. 10, p. 90.

On the conditioned cooling and cubical contraction of a homogeneous sphere. Title. Bull. Phil. Soc. Wash., vol. 10, p. 103.

On the free cooling of a homogeneous sphere. Ann. Math., vol. 3, pp. 75-88.

On a method of computing the secular contraction of the earth. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 37, p. 59.

On the conditioned cooling and cubical contraction of a homogeneous sphere. Ann. Math., vol. 3, pp. 129-144.

1888

On the diffusion of heat in homogeneous rectangular masses, with special reference to bars used as standards of length. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 37, p. 79.

On a method of determining the emissivity of a metallic bar cooling or heating in air. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 37, p. 84.

Laws of frequency of errors of interpolated logarithms, etcetera, dependent on first differences; and a comparison of the theoretical with the actual distribution of the errors of 1,000 interpolated values. Title. Proc. Amer. Assn. Adv. Sci., vol. 37, p. 63.

On the diffusion of heat in homogeneous rectangular masses, with special reference to bars used as standards of length. Ann. Math., vol. 4, pp. 101-127.

On the form and position of the sealevel. Bull. U. S. Geol. Surv., no. 48, 88 pp.

Variation of terrestrial density, gravity, and pressure. Abstract in Bull. Phil. Soc. Wash., vol. 11, p. 580.

Summation of certain complex series. Title. Bull. Phil. Soc. Wash., vol. 11, p. 601.

Mathematical theory of the "stratum of no strain" and its applications to the earth. Abstract in Bull. Phil. Soc. Wash., vol. 11, p. 602.

1889

Mechanical conditions of the earth's mass. Abstract in Bull. Phil. Soc. Wash., vol. 11, pp. 532-533.

Notes on problems in averages. Title. Bull. Phil. Soc. Wash., vol. 11, p. 605.

Some of the greater problems of physical geology. Bull. Phil. Soc. Wash., vol. 11, p. 537.

On the latitudes and longitudes of certain points in Missouri, Kansas, and New Mexico. Bull. U. S. Geol. Surv., no. 49, 132 pp.

Formulas and tables to facilitate the construction and use of maps. Bull. U. S. Geol. Surv., no. 50, 124 pp.

The mathematical theories of the earth. Vice-presidential address before Section of Mathematics and Astronomy of American Association for the Advancement of Science, Toronto meeting. Proc. Amer. Assn. Adv. Sci., vol. 38, 1890, pp. 49-69. Published also in Science, vol. 14, no. 344; Amer. Jour. Sci., vol. 39, no. 227; Amer. Geol., vol. 4, no. 5, and in Rep. Smithsonian Inst., 1890.

The dynamical theory of mercurial thermometers. Abstract in part II of a paper with Prof. Wm. A. Rogers, under the title Concerning thermometers. Proc. Amer. Assn. Adv. Sci., vol. 38, pp. 135-136.

1890

Special laws of the diffusion of heat in homogeneous spheres. Title. Bull. Phil. Soc. Wash., vol. 11, p. 607.

The effects of the atmosphere and oceans on the secular cooling of the earth. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 39, p. 90.

On the deformation of the geoid by the removal, through evaporation, of the water of Lake Bonneville Appendix B of Lake Bonneville, by Grove Karl Gilbert. Monog. U. S. Geol. Surv., vol. 1, pp. 421-424.

On the elevation of the surface of the Bonneville Basin by expansion due to change of climate. Appendix C to Lake Bonneville, pp. 425-426.

Report on astronomical work of 1889 and 1890. Fixation of the 105th meridian in El Paso County, Texas. Bull. U. S. Geol. Surv., no. 70, 80 pp.

1891

Review of Tisserand's Mécanique Céleste. Title. Bull. Phil. Soc. Wash., vol. 11, p. 568.

Review of Tisserand's Mécanique Céleste. Ann. Math., vol. 6, pp. 49-56.

Maxwell's theory of electrostatics. Title. Bull. Phil. Soc. Wash., vol 11. p. 571.

1892

The form and efficiency of the iced bar base apparatus of the United States Coast and Geodetic Survey. Title. Proc. Nat. Acad. Sci., April meeting, 1892.

The iced bar base apparatus of the United States Coast and Geodetic Survey. Title. Proc. Amer. Assn. Adv. Sci., vol. 41, p. 64.

On the general problem of least squares. Title. Proc. Amer. Assn. Adv. Sci., vol. 41, p. 64.

On the use of long steel tapes in measuring base lines. Title. Proc. Amer. Assn. Adv. Sci., vol. 41, p. 146.

On the rectification of a slightly sinuous curve. Title. Bull. Phil. Soc. Wash., vol. 12.

1893

Preliminary account of the iced bar base apparatus of the United States Coast and Geodetic Survey. Amer. Jour. Sci., vol. 45, pp. 33-53.

Recent experience on the United States Coast and Geodetic Survey in the use of long steel tapes for measuring base lines. Trans. Amer. Soc. Civil Eng. (International Engineering Congress, Chicago, 1893), vol. 30, pt. II, pp. 81-107. New York.

The iced bar and long tape base apparatus and the results of measures made with them on the Holton and Saint Albans bases. Pt. II, Appendix no. 8, Rep.. U. S. Coast and Geodetic Surv., 1892, pp. 334-489.

1894

Smithsonian Geographical Tables. Prepared by R. S. Woodward. Published by the Smithsonian Institution, 1894, pp. civ + 182.

Periodic errors of graduated circles. Title. Trans. N. Y. Acad. Sci., vol. 13, p. 205.

Analytical theory of the errors of interpolated values from numerical tables. Abstract in Bull. Amer. Math. Soc., second ser., vol. 1, no. 1.

Review of Byerly's treatise on Fourier's series and spherical, cylindrical, and ellipsoidal harmonics. Ann. Math., vol. 8, pp. 189-191.

An historical survey of the science of mechanics. An address read before the New York Academy of Sciences, November 24, 1894. Science, n. s., vol. 1, pp. 141-157.

On the condition of the interior of the earth. Abstract in Trans. N. Y. Acad. Sci., vol. 14, pp. 72-76.

1895

Review of Ziwet's theoretical mechanics. Science, n. s., vol. 1, p. 20.

Review of Greenhill's treatise on hydrostatics. Science, n. s., vol. 1, p. 269.

On the measurement of horizontal angles. Proc. Eng. Soc. Sch. Mines, Columbia College.

Mechanical interpretation of the variations of latitudes. Astron. Jour., vol. 15, pp. 65-72.

Results of experiments with metallic spheres falling in water. Title. Trans. N. Y. Acad. Sci.

Systems of mechanical units. Abstract in Trans. N. Y. Acad. Sci.

Review of Hancock's Mechanics and Hydrostatics and Glazebrook's Mechanics. Science, n. s., vol. 2, p. 631.

1896

A course of study in the physical sciences. Mechanics. Proc. Soc. Pro. Eng. Ed., vol. 3, pp. 229-241.

Higher mathematics. A text-book for classical and engineering colleges. Edited by Mansfield Merriman and Robert S. Woodward. Chapter on probability and theory of errors, pp. 467-507, by R. S. Woodward. New York, John Wiley and Sons.

1897

Mathematics in "The History of the Smithsonian Institution, 1846-1896," pp. 561-570, Washington, D. C.

The annals of mathematics. The Alumni Bull. Univ. Va., vol. 3, no. 3, pp. 71-72.

Notice of De Volson Wood. Science, n. s., vol. 6, pp. 204-206; also in Proc. Soc. Pro. Eng. Ed., vol. 5, pp. 325-329 (1898).

Modification of the Eulerian cycle due to inequality of the equatorial moments of inertia of the earth. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 46, p. 60.

Integration of the equations of motion of a non-rigid mass for the case of equal principal moments of inertia. Abstract in Proc. Amer. Assn. Adv. Sci., vol. 46, p. 61.

On the cubic equation defining the Laplacian envelope of the earth's atmosphere. Abstract in Bull. Amer. Math. Soc., second ser., vol. 4, pp. 90-91.

On the integration of a system of simultaneous linear differential equations. Abstract in Bull. Amer. Math. Soc., second ser., vol. 4, pp. 91-92.

On the gravitational constant and the mean density of the earth. Astron. Jour., vol. 18, pp. 121-122.

1898

On the differential equation defining the Laplacian distribution of density, pressure, and acceleration of gravity in the earth. Abstract in Bull. Amer. Math. Soc., second ser., vol. 4, pp. 177-178.

On the significance of the product of the gravitational constant and the mean density of the earth. Abstract in Bull. Amer. Math. Soc., second ser., vol. 4, p. 294.

Some recent works on mechanics. Reviews of Routh's Analytical Statics, Appel's Traité de mécanique rationelle, Du Bois's Elementary Principles of Mechanics, Tait's Dynamics, Wright's Elements of Mechanics, Perry's Applied Mechanics, and Klein and Sommerfield's Ueber die Theorie des Kreisels. Science, n. s., vol. 8, pp. 190-195.

On the mutual gravitational attraction of two bodies whose mass distributions are symmetrical with respect to the same axis. Abstract in Bull. Amer. Math. Soc., second ser., vol. 5, pp. 114-116.

1899

A national observatory. Science, n. s., vol. 9, pp. 470-471.

1900

Some recent works on mechanics. Reviews of Love's Theoretical Mechanics and H. von Helmholtz's Vorlesungen ueber Theoretische Physik. Science, n. s., vol. 10, pp. 180-183.

Poincaré's Cours de Physique Mathématique. Science, n. s., vol. 10, pp. 213-217.

The century's progress in applied mathematics. Presidential address to the American Mathematical Society. Bull. Amer. Math. Soc., second ser., vol. 4, pp. 133-163; also in Science, n. s., vol. 11, nos. 263, 264,

1900. The same was translated into Polish by Dr. S. Dickstein and published in Wiadmosci Matematyczne, tom V, zeszyt, 1, 2, 3, pp. 17-51, under the title Postepy matematyki stosowanej w XIX stuleciu.

An elementary method of integrating certain linear differential equations. Bull. Amer. Math. Soc., second ser., vol. 6, pp. 369-371.

The advancement of science. Inaugural address of the President of the American Association for the Advancement of Science. Science, n. s., vol. 11, pp. 12-15.

Reviews of memoirs presented to the Cambridge Philosophical Society on the occasion of the jubilee of Sir George Gabriel Stokes, Bart. Scientific papers by Peter Guthrie Tait, vol. 2; papers on mechanical and physical subjects by Osborne Reynolds.

1901

Observation and experiment. Presidential address to the New York Academy of Sciences. Science, n. s., vol. 13, pp. 521-530. Published also in Ann. N. Y. Acad. Sci., vol. 14, pp. 69-84.

The effects of secular cooling and meteoric dust on the length of the terrestrial day. Astron. Jour., vol. 31, pp. 169-175.

The progress of science. Presidential address to the American Association for the Advancement of Science. Science, n. s., vol. 14, pp. 305-315; Pop. Sci. Mo., vol. 59, pp. 513-525; Nature, vol. 44, pp. 498-502.

Some recent works on mechanics. Reviews of Theoretical Mechanics, by L. M. Hoskins; The Principles of Mechanics, by Frederick Slate; Theoretical Mechanics, by W. W. Johnson, and Ad. Wernicke's Lehrbuch der Mechanik. Science, n. s., vol. 14, pp. 571-573.

Review of Riemann's Die partiellen Differentialgleichungen der mathematischen Physik. Science, n. s., vol. 14, pp. 610-611.

1902

Measurement and calculation. Presidential address to the New York Academy of Sciences. Science, n. s., vol. 15, pp. 961-971.

1903

Education and the world's work of today. Commencement address read at Rose Polytechnic Institute, June 11, 1903. Terre Haute Evening Gazette of June 11, 1903; Science, n. s., vol. 18, pp. 161-169.

The International Conference of Arts and Science. Science, n. s., vol. 18, pp. 302-303.

A new method of integrating one of the differential equations of the theory of heat diffusion. Phys. Rev., vol. 16, pp. 176-177.

1904

The unity of physical science. Address before the Division of Physical Science. International Congress of Arts and Science, Saint Louis, September-October, 1925. Science, n. s., vol. 20, pp. 417-426.

Academic ideals. Address at the opening of Columbia University, September 28.

1905

Academic ideals. Science, n. s., vol. 21, pp. 41-46.

Report of the president of the Carnegie Institution of Washington. Year Book no. 4, pp. 15-33.

1906

Report of the president of the Carnegie Institution of Washington. Year Book no. 5, pp. 15-37.

The Carnegie Institution of Washington. Science, n. s., vol. 23, pp. 121-133.

1907

Report of the president of the Carnegie Institution of Washington. Year Book no. 6, pp. 13-38.

The Carnegie Institution of Washington. Science, n. s., vol. 25, pp. 55-60.

Joseph Henry. Pop. Sci. Mo., vol. 70, pp. 299-300.

1908

Report of the president of the Carnegie Institution of Washington. Year Book no. 7, pp. 15-36.

Engineering mathematics. Science, n. s., vol. 28, pp. 134-138.

Our educational opportunities and how to use them. Commencement address at Carnegie Technical Schools, Pittsburgh.

1909

Report of the president of the Carnegie Institution of Washington. Year Book no. 8, pp. 17-39.

Conduct of scientific work under the United States Government. Science, n. s., vol. 29, pp. 217-220.

1910

Report of the president of the Carnegie Institution of Washington. Year Book no. 9, pp. 7-34.

The atmosphere. Bull. Mt. Weather Obs., vol. 2, pt. 5, pp. 1-11.

1911

Report of the president of the Carnegie Institution of Washington. Year Book no. 10, pp. 5-29.

1912

Report of the president of the Carnegie Institution of Washington. Year Book no. 11, pp. 5-28.

1913

The orbits of freely falling bodies. Science, n. s., vol. 35, pp. 315-319.

Report of the president of the Carnegie Institution of Washington. Year Book no. 12, pp. 5-35.

The orbits of freely falling bodies. Astron. Jour., vol. 28, pp. 17-32.
The laws of falling bodies. Abstract in Jour. Wash. Acad. Sci., vol. 3, p. 426.

1914

The Carnegie Institution of Washington. Science, n. s., vol. 39, p. 225.
Report of the president of the Carnegie Institution of Washington. Year Book no. 13, pp. 5-39.

1915

Freely falling bodies. Science, n. s., vol. 41, pp. 492-495.
Report of the president of the Carnegie Institution of Washington. Year Book no. 14, pp. 1-29.
Compressibility of the earth's mass. Abstract in Jour. Wash. Acad. Sci., vol. 5, p. 251.
The earth. Abstract in Jour. Wash. Acad. Sci., vol. 5, p. 554.

1916

Extraction of square roots of numbers. Abstract in Jour. Wash. Acad. Sci., vol. 6, pp. 299-300.
Proceedings of the Second Pan American Scientific Congress. Section 2, Astronomy, Meteorology, Seismology; R. S. Woodward, chairman.
Report of the president of the Carnegie Institution of Washington. Year Book no. 15, pp. 1-15.

1917

The Carnegie Institution of Washington. Science, n. s., vol. 45, pp. 204-208.
Report of the president of the Carnegie Institution of Washington. Year Book no. 16, pp. 5-35.
The Carnegie Institution of Washington and the public. Science, n. s., vol. 46, pp. 573-581.

1918

Report of the president of the Carnegie Institution of Washington. Year Book no. 17, pp. 5-30.

1919

The Carnegie Institution of Washington. Science, n. s., vol. 50, pp. 529-533.
Report of the president of the Carnegie Institution of Washington. Year Book no. 18, pp. 5-32.

1920

Report of the president of the Carnegie Institution of Washington. Year Book No. 19, pp. 1-24.

1922

The calculus of harmonics and preharmonics and their application in hydromechanics. Abstract in Jour. Wash. Acad. Sci., vol. 12, p. 268.

Alfred Goldsborough Mayor. Science, n. s., vol. 56, p. 68.

1923

The compressibility of the earth. Abstract in Jour. Wash. Acad. Sci., vol. 13, p. 44.

Some extensions in the mathematics of hydromechanics. Proc. Nat. Acad. Sci., vol. 9, pp. 13-18.

Edwin B. Frost

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OF

EDWIN BRANT FROST

1866–1935

BY

OTTO STRUVE

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1937

EDWIN BRANT FROST

1866–1935

BY OTTO STRUVE

As I write this memoir of the life of Edwin Brant Frost I am deeply conscious of the fact that the most characteristic feature of his life's work was the international scope of his scientific interests. Mr. Frost was one of the most outstanding representatives of a large group of American scientists who recognized no narrow national barriers in science. Throughout his long and distinguished career he worked for international cooperation in astronomy—his chosen field—and many of the recognized achievements of international meetings and committees owe their success, directly or indirectly, to his efforts.

The disturbing political events of the past few years and months tend only to strengthen our realization of the enormous value of Frost's efforts. Since the beginning of the world war conditions have not been conducive to the development of true international cooperation. There are now fewer men in science, who, like Frost, had an opportunity to study in Europe. Likewise, there have been fewer foreign students in America. Regulations of foreign governments concerning the exportation of currency and political restrictions have, for many years, prevented the normal exchange of fellows, traveling students, and visiting scientists. Even the exchange of books and periodicals is becoming increasingly difficult because of monetary restrictions or because of rapid fluctuations in the foreign exchange.

When Professor George E. Hale organized the *Astrophysical Journal* in 1895, he added to the name of the new periodical the subtitle: *An International Review of Spectroscopy and Astronomical Physics.* In a plan of publication formulated in Berlin it was decided "that five associate editors be chosen to represent Germany, Great Britain, France, Italy and Sweden on the editorial staff, for it was felt from the first that unless the *Journal* were made truly international in character it could not be a success." The original board of editors consisted of

Hale and Keeler. Frost, Ames, Campbell, Crew, and Wadsworth acted as assistant editors. Cornu, Dunér, Huggins, Tacchini, Vogel, Hastings, Michelson, Pickering, Rowland, and C. A. Young were the associate editors. After he was made acting editor in 1902, together with Hale, Frost continued the international policy outlined by the latter, and to this day the *Astrophysical Journal* includes in its list of collaborating editors a group of five distinguished astronomers and physicists of other countries.

When, during the war, Professor Elis Strömgren organized at Copenhagen his international bureau of astronomical information between the belligerent countries, Frost whole-heartedly supported it. When after the end of the great war German and Austrian observatories were unable to pay the subscription price for the *Astrophysical Journal,* Frost devised a plan whereby the *Journal* was sent to them free, payment being deferred until economic conditions in central Europe would improve.

Having learned of the distressing conditions in famine-stricken Russia, Frost organized in the spring of 1922 an informal committee (with the cooperation of Professor Van Biesbroeck and the writer) for the relief of Russian astronomers. This committee collected the considerable sum of $2,556.12 among American astronomers and friends of science, and disbursed the entire amount to the suffering astronomers in Russia, mostly in the form of Mr. Hoover's ARA food packages. Although some efforts had been made earlier to help the astronomers at Pulkovo, the immediate stimulus for the formation of Frost's committee came through a letter to him from the distinguished director (now deceased) of an eastern observatory in Russia. This letter begins as follows: "The severe conditions of famine which now prevail in Russia compel me as director to appeal to you for help for the staff of the observatory . . . " Touching are some of the replies acknowledging the receipt of the packages: "We Russian astronomers during many years have been separated from the whole civilized world, but now we feel our bonds renewed with the men of learning and the progress of universal science." It was indeed a satisfaction for Mr. Frost

to learn that a ten-dollar food package had carried two persons through a month.

In his autobiography "An Astronomer's Life" Mr. Frost has given an excellent account of his life. He was born on July 14, 1866, at Brattleboro, Vermont, the descendant of one Edmund Frost, who was born about 1600 in England, and came to America in 1635 in order "to escape the more savage oppression of England." Edwin Brant's father—Carlton Pennington Frost—was a professor and dean of the medical school at Dartmouth College. Edwin Brant Frost spent many years of his early life at Hanover. In 1882—about a month before his sixteenth birthday—he passed the entrance examinations at Dartmouth College. In his senior year he became interested in astronomy. Professor C. A. Young had moved to Princeton in 1877, but Frost knew him and his family quite intimately and Fred, the younger son of Professor Young, had been Edwin Brant's chief playmate. In August, 1885, a nova appeared in the great spiral nebula of Andromeda. It was then believed that "we might be observing the sudden transformation of the nebula into a star along the lines of the theory of Laplace." Frost was greatly interested in the new phenomenon and chose it as the topic of his senior class oration. He graduated in 1886, with a speech on the influence of astronomy upon literature.

After graduation, Frost enrolled as a post-graduate in the department of chemistry, and almost at once was appointed assistant under Professor Bartlett. For a short time he taught school at Hancock, New Hampshire. Early in 1887 he accepted an invitation from Professor C. A. Young and went to Princeton to take a practical course in astronomy, being a guest in the Young household. In the fall of 1887, Frost was appointed instructor in physics and astronomy at Dartmouth College. He was then only 21 years old. In the summer of 1888 he assisted Professor Young in reading the proofs of the latter's textbook on *General Astronomy*. This excellent book made a great impression upon the young astronomer. With his brilliant memory he was able to retain until his death an almost photographic mental record of nearly every page! Even after total blindness had

prevented him from consulting this book, he could unerringly point out the page and paragraph when he wanted someone to read a particular passage to him.

In 1890 Frost took leave of absence from Dartmouth and went first to England where, among others, he met Sir William and Lady Huggins. At Greenwich he met the chief assistant, H. H. Turner—later Savilian Professor of Astronomy at Oxford—who remained one of his life-long friends. After a short stay at Strassbourg, where he attended lectures by Kohlrausch, Wiener, Becker and others, and where he became acquainted with other graduate students and assistants: Peter Lebedeff of Russia, H. Kobold (now in Kiel), J. Halm (later astronomer at the Cape of Good Hope), Frost went to Potsdam to work under Vogel. In 1891 he was appointed assistant at Potsdam under Scheiner and Vogel. Nova Aurigae provided much excitement that year, and Vogel assigned to Frost the task of observing its spectrum. It was through this somewhat accidental occurrence that Frost embarked upon the study of stellar spectra, which later became his special field of research.

Scheiner had just published an important new book on the *"Spectral Analyse der Gestirne,"* and Frost decided to translate it into English. This translation, containing many additions and revisions by the translator, was printed by Ginn and Company in 1898. It remained the standard textbook of astrophysics in the English language for almost twenty years.

In the autumn of 1892 Frost returned to Dartmouth College as assistant professor of astronomy. In the same year he met Dr. George E. Hale at the Rochester meeting of the American Association for the Advancement of Science. It was at this meeting that Hale learned from Alvan G. Clark that two excellent 40-inch discs cast by Mantois of Paris were being offered for sale. Frost probably did not then realize that he would be custodian of these discs for more than a quarter of a century.

In 1897 Frost attended the conference of astronomers held in connection with the dedication of the Yerkes Observatory at Williams Bay, Wisconsin. The following April Professor Hale invited him to become professor of astrophysics at the Yerkes Observatory of the University of Chicago.

When Hale organized the famous expedition from the Yerkes Observatory to Pasadena, which formed the beginning of the Mount Wilson Observatory, Frost remained at Williams Bay as acting director. In 1905, upon Dr. Hale's resignation, he was appointed director—a position which he held until his retirement in 1932.

In the night of December 15, 1915, Frost lost the use of his right eye. He writes in his autobiography: ". . . I was working alone at the forty-inch telescope, photographing the spectrum of a rather faint star, by name 20 Persei. I had difficulty in seeing the divisions of the circle and in guiding after I had brought the star into proper position upon the slit of the spectroscope. I carried on the exposure until an assistant arrived and then found that vision in the right eye was greatly reduced. I had my own fear of what was the trouble, because my mother had suffered from a detached retina. My fears were unfortunately well founded." Frost retained the use of his left eye and was able to read with it. In 1921 he lost the use of this second eye. I clearly remember how, on October 10, of that year, Mr. Frost met me at the station in Williams Bay when I arrived from Constantinople. With Professor Van Biesbroeck to help him overcome the restrictions of his vision (due then mostly to nearsightedness in the remaining eye) he drove his own car to the Observatory, where he introduced me to my duties as his assistant. A few nights later I was observing at the forty-inch refractor, and forgot to mark the spectrograms for identification. The next morning Mr. Frost came to my office and offered to help me identify the stars from their spectra. I lined them up for him in the Hartmann spectrocomparator, but, to his surprise, he could not see the lines. It was found later that a hemorrhage had occurred in the good eye; and a rapidly forming cataract—which never ripened and thus could not be removed—soon completely extinguished his vision.

The tragedy of a great astronomer becoming blind cannot adequately be described. Mr. Frost gave an example to everyone who knew him of courage and cheerfulness. He adjusted himself to his lack of vision, and continued, for eleven years, to direct the Yerkes Observatory and to edit the *Astrophysical*

Journal. One of his biographers fittingly wrote of him: "This cruel malady—and what could be harsher than blindness to an astronomer?—deafness to a musician perhaps—brought out such magnificent traits of character and aroused in those who saw him go about his ways in cheerful mien, such quick sympathy and profound admiration that the influence of his dark years upon his fellow-men was perhaps even greater than those devoted actively to research." Probably no other scientist has ever been admired and loved so much by those who knew him or knew of him. Children used to gather around him and hear his stories about the stars, or the birds which he could imitate to perfection, or the trees which he had planted in the park surrounding the Observatory. Grown-up people of all classes of life listened reverently to him when, on a Saturday afternoon, he explained to them the operation of the great telescope. At the opening of the Century of Progress Exposition in Chicago in 1933, when the light of Arcturus was used to turn on the illumination of the Fair grounds on the shore of Lake Michigan, Mr. Frost gave the principal address which was heard by many thousands of visitors in Chicago and by millions of listeners over the radio. A well-known astronomer dedicated to him a large volume of astronomical research, in the following words:

"TO
EDWIN BRANT FROST
MY FIRST TEACHER OF ASTRONOMY
THIS VOLUME
IS GRATEFULLY INSCRIBED
IN THAT NIGHT INTO WHICH HE HAS FOLLOWED
GREAT GALILEO MAY HE STILL SEE WITH THE
EYES OF HIS DEVOTED AND REVERING STUDENTS."

Frost's astronomical work began in 1889 at the Shattuck Observatory of Dartmouth College. He observed sun spots, comets, occultations, and in 1891 he computed the orbit of Comet 1890 IV (Zona). In 1892 he published an important paper on the thermal absorption in the solar atmosphere, which was inspired by H. C. Vogel at the Potsdam Observatory. In later years Frost retained his interest for solar investigations: he was

an ardent observer of the flash spectrum during solar eclipses. At the eclipse of May 28, 1900, he obtained a series of excellent exposures of the flash spectrum and his measurements of the wave-lengths and identifications of the lines were among the best at that time, and formed the basis for later work by other observers.

The great majority of Frost's scientific contributions deal with the spectra of the stars and, in particular, with the determination of their motions in the line of sight.

The original equipment of the Yerkes 40-inch refractor included a stellar spectrograph designed by Professor Keeler of the Allegheny Observatory and constructed by Mr. Brashear of Pittsburgh. This instrument was described by Professor Hale and Mr. Ellerman, and was used by them to great advantage for a study of the spectra of very red stars. However, the mechanical parts were not sufficiently stable and free of flexure to permit its use for the determination of radial velocities. Accordingly, Frost decided to build a new modern spectograph intended primarily for radial-velocity work. In 1899 Miss Catherine W. Bruce made a gift to the Yerkes Observatory of $2300 for the new instrument, and in January, 1902, Frost was able to publish in the *Astrophysical Journal* a complete description of the Bruce spectrograph, together with some preliminary measurements of stellar motions.

The Bruce spectrograph remained Frost's principal instrument, and with it he accumulated an enormous amount of material on the spectra of the hottest stars, spectroscopic binaries, novae and variable stars. It is of interest in this connection that the Bruce spectrograph has for over thirty-five years been the principal spectrographic instrument of the Yerkes Observatory. Without major changes it has served two generations of astronomers, and even today it continues to produce results which are equal to those obtained elsewhere. With a short-focus camera designed by Dr. G. W. Moffitt and with one of the original prisms made of Mantois glass, recently refigured by Bausch and Lomb, we are able to photograph the spectra of stars of the eleventh photographic magnitude in a few hours, with a dispersion of about 120 A/mm. at λ 4500. The defini-

tion given by the single prism is excellent: with a longer camera it has recorded a vast number of spectral lines never before observed with any instrument.

Incidentally, the old Brashear spectrograph of the 40-inch telescope was transferred by Frost to the 12-inch refractor, where it was used for many years in the observation of prominences. A few years ago it was again used for stellar work by Messrs. Elvey and Keenan, who obtained with it the total intensities of Hα in several stars. Quite recently this old spectrograph, equipped with a single prism and with a new short camera, has again been transferred to the 40-inch, where Dr. G. P. Kuiper uses it for the classification of the spectra of stars as faint as magnitude 13.

Frost's first work with the Bruce spectrograph dealt with the motions of the helium stars. These stars had been somewhat neglected by other observers, partly because their lines are often ill-defined and partly because the laboratory wave-lengths of many of the lines were not adequately known. In collaboration with Dr. W. S. Adams, Frost overcame these difficulties and in 1904 there appeared in the *Publications of the Yerkes Observatory* a paper, under joint authorship, on the "Radial Velocities of Twenty Stars having Spectra of the Orion Type." A careful investigation of the systematic errors of the instrument preceded the work, and the precision obtained for the twenty stars was very gratifying. Although the number of stars was not sufficient to make a solution for the solar motion, "the distribution of positive and negative velocities shows clearly the direction of the motion of the sun in space." The mean motions of the helium stars were found to be surprisingly small, only 7.0 km/sec as the mean of the twenty radial velocities corrected for solar motion. It was already known that the average velocities of the cooler stars were considerably larger. Thus, Frost and Adams brought out the significant fact that the average motions of the stars were not the same for all spectral types. This result has been of fundamental importance in all later investigations concerning the dynamics of the stellar system.

But the most significant result was stated by the authors in the following short sentence: ". . . if the sign be regarded, the mean becomes +4.6 km/sec." In other words, after the component of the solar motion had been subtracted from the measured velocities, the mean velocity with regard to the sign was not zero or close to zero, but was of the same order of magnitude as the mean velocity taken without regard to sign. The authors had thus, for the first time, recorded the famous K-effect in the motions of the helium stars, which, literally interpreted, means that the system of B-type stars, as a whole, expands with a velocity of 4.6 km/sec.

In 1910 Frost, in collaboration with J. C. Kapteyn, returned to the question of the mean motion of the helium stars. After having discussed the solar motion from the large amount of radial velocity material collected by Frost, the authors remark: ". . . meanwhile our numbers bring out a somewhat unexpected fact, namely that the velocity of the sun relative to the stars near the apex is found to be very different from that relative to the stars near the antapex. To show this more clearly, a separate solution was made for the stars for which $\lambda < 90^\circ$ and for which $\lambda > 90^\circ$. We thus find:

Near apex $v = -18.38 \pm 1.40$ km, from 32 stars
Near antapex $v = -28.38 \pm 1.36$ km, from 29 stars
Simple mean $v = -23.38$ km, from 61 stars

The difference is very considerable and cannot well be attributed to accidental error alone."

This peculiar phenomenon of expansion of the system of helium stars has been the subject of many later investigations, and even today it has only been partly explained. Kapteyn and Frost were aware that "a constant error, depending on instrumental and personal influences and on errors in the assumed wave-lengths of the lines both in the star spectrum and in the comparison spectrum such that the positive velocities would result too great, might of course explain the difference." To test this possible explanation Frost devoted much time and energy to the determination of the wave-lengths and to the elimination of systematic errors in radial velocities. But the

K-effect persisted. It is of historic interest that Kapteyn and Frost concluded that "the most plausible [explanation] would seem to be that either the stars near the apex, or those near the antapex, or both, belong in unequal numbers to the two great star-streams." A somewhat similar explanation, in terms of systematic motions among the brighter helium stars, was recently proposed by Paskett and Pearce, at Victoria.

The final radial velocity results obtained at the Yerkes Observatory were published by Frost, Barrett and Struve in the *Astrophysical Journal,* 64, 1, 1926, and in the *Publications of the Yerkes Observatory,* Volume VII, Part 1, 1929. The former contains the velocities of 368 B-type stars and the latter those of 500 A-type stars.

One of the earliest results of Frost's work on radial velocities was the discovery of a surprising number of new spectroscopic binaries. The pages of the *Astrophysical Journal* were virtually swamped with announcements of new binaries. Their number grew so rapidly that Frost was, at times, concerned over the question whether enough stars of constant velocity would be left to provide sufficient material for a study of the motions of the system of helium stars. He and his associates, therefore, began the laborious task of determining the orbits of some of these binaries.

On May 14, 1902, Frost made an important discovery, although at the time he himself probably did not realize how deeply it would affect our knowledge of the stars. On that particular night he took two spectrograms of the bright B-type star β Cephei. During the winter of 1901-1902 he had measured eleven spectrograms of this star and had found it to possess a variable velocity. He states in his first announcement concerning β Cephei: "We had assumed from the first plates that the period would be rather long, but a suspicion to the contrary led me to take two plates on the night of May 14, and during the interval of five and one-half hours the velocity changed 14 km, or nearly half of the whole range so far observed." Such rapid variations in radial velocity were quite unheard of in 1902, and Frost diligently continued his observations. Four years later he announced that the period is $4^h34^m11^s$, and that the velocity

curve is nearly symmetrical, with a range of 34 km/sec. The shortest period of any spectroscopic binary previously known was 1.45 days in the case of μ Scorpii and *V* Puppis. Frost noticed that the radius of the orbit of β Cephei, computed from the velocity curve, would be inconceivably small—only 45,000 kms—and he suggested that the binary hypothesis could only be true if the inclination of the orbit were close to 0°. He says: ". . . if the radius of the orbit of the brighter star is assumed for the moment to be the same as that found by Vogel for Algol (1.6 million kms), then the inclination of the plane would lack only about 1½° of 90°; and the observed projected velocity would have to be increased nearly forty-fold, yielding an actual velocity of over 600 km/sec."

β Cephei was not then known to vary in light, and this was believed to support the hypothesis of a small inclination. Frost was therefore immensely interested when, in 1913, Guthnick announced that the light of β Cephei varies with an amplitude of 0.05 magnitude, the period of this variation being identical with that found by Frost. However, the light curve did not resemble those of ordinary eclipsing variables. Furthermore, it seemed inconceivable that the small range in radial velocity could at all be reconciled with an eclipse. The problem of β Cephei remained unsolved for many years.

Frost clearly understood that in order to explain the apparent contradictions in β Cephei, more observational material on other stars was required, and he started systematic observations for the detection of other similar objects. Every star known to have a variable radial velocity, for which no period had been found, was placed on the observing program and long series of spectrograms were obtained on a few single nights. Most of these cases yielded only constant velocities, but a small number of stars were gradually discovered which seemed to resemble β Cephei. Other observatories added to the list, and by 1921 the number was sufficient for a preliminary discussion. This discussion Mr. Frost assigned to me, a few weeks after my arrival at the Yerkes Observatory. For spectroscopic binaries of types O, B and A, the amplitude of the velocity curve increases, on the average, rapidly with decreasing period, in accord-

ance with Kepler's third law. But this increase continues only until a period of about 1.3 days is reached. For still shorter periods the amplitude again decreases. This can mean only one thing: β Cephei and all similar stars are not true binaries. They resemble more closely the Cepheid variables, but differ from them by the small amplitude of their light variations. Many representatives of this group display irregularities in their light curves as well as in their velocity curves. The entire group has often been designated as the β Canis Majoris stars, and Henroteau, who, I believe, first introduced this term, counted β Cephei among them. The name is, however, historically incorrect, and scientifically misleading. β Cephei was, without doubt, the first and most typical representative of the mysterious group of quasi-Cepheids of early type and of very short period. While irregularities are present both in its velocity curve and light curve, it promises to give valuable results to the observer who can combine photoelectric observations of the light with accurate measurements of the radial velocity. We know surprisingly little concerning these stars, and Frost's work on β Cephei will become increasingly appreciated as we begin to unravel their secrets.

In 1917 Frost started a long series of observations of the peculiar spectroscopic binary and eclipsing variable ε Aurigae. Its period had been found by Ludendorff to be 27 years, and it was important to determine the spectrographic orbit as well as to elucidate some very strange phenomena reported by the Potsdam observers during the eclipse of 1902. This work was continued by the present writer and by Elvey, and the results of the Yerkes Observatory investigations were published by Frost, Struve and Elvey in the *Publications of the Yerkes Observatory*, Volume 7, Part 2, 1932. The spectrographic observations made during the eclipse revealed an unsymmetrical broadening of the lines towards the red during the partial phase preceding total eclipse and towards the violet following total eclipse. The authors interpreted this phenomenon as being produced by the absorption within the rotating outer layers of the eclipsing star. Almost simultaneously Guthnick advanced the same hypothesis in the case of ζ Aurigae. These

two stars have given the first indication of the existence in certain super-giants of tenuous atmospheres (or reversing layers) extending to heights of more than one astronomical unit. In most ordinary stars the height of the reversing layer is of the order of a few hundred kilometers. The complete interpretation of the system of ε Aurigae was not possible in 1932, and there remained a serious discrepancy between the evidence furnished by the velocity curve and that furnished by the light curve. The latter suggests that the eclipse of the bright F star is total. Consequently, at constant minimum we should observe the spectrum of the eclipsing star alone. Yet, the spectral lines at minimum are, with very few exceptions, stronger replicas of the normal F-star lines. On the other hand, at maximum separation of lines, around 1925, only the normal F star was visible; the other set of lines was completely absent. Recent progress in the study of ζ Aurigae and VV Cephei has paved the way for the explanation of this apparent paradox. It is expected that the riddle of ε Aurigae will soon be solved—thus bringing to a conclusion a series of investigations inaugurated by Frost twenty years ago.

From the beginning of his work with the Bruce spectrograph Mr. Frost was interested in the problem of systematic errors in radial velocities; his efforts, over a period of thirty years, have profoundly influenced the methods of radial-velocity observers. In 1902 he sent a circular letter to some of the world's leading observatories inviting them to cooperate in the observation of a selected list of ten "fundamental velocity stars." As Frost remarked, "the history of progress in other fundamental measurements would suggest that systematic differences between the results at different observatories are likely to become more apparent as the accuracy of the determinations increases." The observations of planets or of the moon give, of course, an excellent check for each individual observatory, but since the latter have extended surfaces they illuminate the slit of the spectrograph uniformly. Stars which are more nearly point sources must be "guided" on the slit. Lack of exact centering of the star image on the slit caused, for example, by atmospheric dispersion or by optical defects in the guiding system, introduce a

troublesome systematic error which is not present in planetary observations. Furthermore it is important to have the test objects well distributed over the sky so that observations can be made at all times. This would not always be true in the case of planets.

As a result of Frost's continuous efforts a large mass of data on the standard velocity stars has been accumulated at various observatories. In 1925 the International Astronomical Union appointed a sub-committee of the commission on radial velocities for the selection of a new list of standard velocity stars. Frost was the chairman of this committee. The final list published in the *Transactions of the International Astronomical Union,* Vol. III, 1928, contains 28 stars in both hemispheres; this list includes most of Frost's original standard stars. The adopted standard velocities are based upon several thousand individual observations made at twelve observatories. They are, to date, the most precise set of radial velocities known. The probable error for each star is of the order of ± 0.1 km/sec.

The final results of the Yerkes observations of standard velocity stars were used for the derivation of a set of stellar wave-lengths for use with dispersions of around 10 A/mm at λ 4500. These were published as a "List of Recommended Wave-lengths for Three-Prism Dispersion" in the *Transactions of the International Astronomical Union,* Vol. V, 1935.

After his appointment as director of the Yerkes Observatory, Mr. Frost was obliged to devote a large part of his time to administrative duties. But he took a keen interest in the work of his associates. Of the original staff, after Hale, Ellerman, Adams, Ritchey and Pease had gone to Mount Wilson, Burnham, Barnard and Barrett remained permanently with Frost at Yerkes. Schlesinger soon left to become the director of the Allegheny Observatory. Fox remained until 1909 when he was appointed director of the Dearborn Observatory. Of Mr. Frost's later associates we must mention Mitchell, Slocum, Lee, Van Biesbroeck and Ross. Mr. Frost was especially fortunate in having with him as scientific secretary of the Observatory a close friend and loyal collaborator—Professor Storrs B. Barrett.

Mr. Frost had many honors. The University of Cambridge,

England, conferred upon him the honorary degree of D. Sc. in 1912. He also had a D. Sc. from Dartmouth in 1911. He was elected a member of the National Academy of Sciences in 1908; of the American Philosophical Society in 1909; of the American Academy of Arts and Sciences in 1913; of the Washington Academy of Sciences in 1915. He was made a foreign associate of the Royal Astronomical Society in 1908. He held honorary memberships in the Societa degli Spettroscopisti Italiani; the Astronomical Society of Mexico, the Royal Astronomical Society of Canada, and the Russian Astronomical Society.

He was married in 1896 to Miss Mary E. Hazard of Boston. His family life was a happy one, and he has set a monument to it in his book "An Astronomer's Life," which is dedicated to Mrs. Frost. Touching are the pages in which he describes her faithful help in preparing the manuscript for the book, in assisting him with his lectures and in smoothing over the many difficulties which came to him with his blindness. Three children survive him: Miss Katharine Brant Frost is in business in Chicago; Mr. Frederick H. Frost, a paleobotanist, is assistant superintendent of the Warren Paper Company in Portland, Maine; and Mr. Benjamin DuBois Frost is a business man in New York City.

Mr. Frost died on May 14, 1935, after an operation at Billings Hospital of the University of Chicago.

BIBLIOGRAPHY OF
EDWIN BRANT FROST

List of Abbreviations

A. and Ap. = Astronomy and Astrophysics.
A.J. = Astronomical Journal.
A.N. = Astronomische Nachrichten.
Ap.J. = Astrophysical Journal.
J.Can.R.A.S. = Journal of the Royal Astronomical Society of Canada.
Mem. Nat. Ac. Sc. = Memoirs of the National Academy of Sciences.
Mem. Spettr. It. = Memorie della Societa degli Spettroscopisti Italiani.
N.S. = New Series.
P.A. = Popular Astronomy.
Proc. A.A.A.S. = Proceedings of the American Association for the Advancement of Science.
Proc. Am. Phil. Soc. = Proceedings of the American Philosophical Society.
Proc. Nat. Ac. Sc. = Proceedings of the National Academy of Sciences.
Publ. = Publication.
Publ. Am. Astr. Soc. = Publications of the American Astronomical Society.
Publ. A.S.P. = Publications of the Astronomical Society of the Pacific.
Publ. As. and Ap. Soc. Am. = Publications Astronomical and Astrophysical Society of America.
Sid. Mess. = Sidereal Messenger.

1888

Summary of Solar Observations (at the Shattuck Observatory of Dartmouth College). A.J. 8, 182.
Occultation of Jupiter. A.J. 8, 190.

1889

Solar Observations at Shattuck Observatory. A.J. 9, 67-68, 156.
Ring-Micrometer Observations of Comet *d* 1889, made at the Shattuck Observatory. A.J. 9, 134.

1890

The Relative Activity in the Two Solar Hemispheres. Sid. Mess. 9, 109-111.
Dartmouth Notes. Sid. Mess. 9, 183.
Observations of Comet *a* 1890, made at the Shattuck Observatory. A.J. 10, 32.
Solar Observations at Shattuck Observatory, January to July, 1890. A.J. 10, 46-48.
Elements of Comet 1890 IV (Zona). A.J. 10, 175.

1891

Observations of Comet 1890 II, made at the Observatory of Dartmouth College with the 9.4 inch Equat. and Ring-Micrometer. A.N. 126, 61-62.

1892

Observations on the Thermal Absorption in the Solar Atmosphere, made at Potsdam. A.N. 130, 129-146; A. and Ap. 11, 720-737 (with additions).

1893

Photometric Observations of the Planets. A. and Ap. 12, 619-622.

The Potsdam Spectrograph. A. and Ap. 12, 150-156.

1894

Units of Velocity in the Line of Sight. A. and Ap. 13, 160.

1895

Review of: *The Total Solar Eclipse of April 16, 1893. Report on the Results Obtained with the Slit Spectroscopes,* by E. H. Hills. Ap.J. 1, 91-92.

Review of: *Preliminary Report on the Results Obtained with the Prismatic Camera During the Total Eclipse of the Sun, April 16, 1893,* by J. Norman Lockyer. Ap.J. 1, 91-92.

Review of: *Étude sur le spectre de l'étoile variable δ Cephei,* by A. Belopolsky. Ap.J. 1, 263-265.

Note on a Differential Method of Determining the Velocity of Stars in the Line of Sight. Ap.J. 2, 235-236.

Note on Helium in β Lyrae. Ap.J. 2, 383-384.

Review of: *Untersuchungen über die Spectra der Helleren Sterne,* by J. Scheiner. Ap.J. 2, 386-392.

Helium, Astronomically Considered. Publ. A.S.P. 7, 317-326.

A New Method of Determining Velocity in the Line of Sight (Note). Observatory 18, 394.

On the Spectrum of Beta Lyrae. Proc. A.A.A.S. 44, 23-29.

1896

Review of: *Spectroscopy of Binary Systems* by T. J. J. See. Ap.J. 3, 232-234.

On the Level of Sun-Spots. Ap.J. 4, 196, 204; Observatory 19, 394-398, 437-439.

Experiments on the X-Rays. Science N.S. 3, 235-236, 465-467.

1897

Review of: *Die Schwankungen im Wasserdampfgehalte der Atmosphäre auf Grund Spectroskopischer Untersuchungen,* by Th. Arendt. Ap.J. 5, 152-153.

Note on Dr. Arendt's Spectroscopic Investigation of the Variation of Aqueous Vapor in the Atmosphere. Ap.J. 6, 57.

Astrophysical Notes. Science N.S. 6, 587-588.
The Yerkes Observatory. Science N.S. 6, 721-724.
Southern Star Clusters. Science N.S. 6, 832-834.
A treatise on astronomical spectroscopy; being a translation of: Die Spectranalyse der Gestirne, by Dr. J. Scheiner. Ginn & Company, Boston and London.
Review of: *Die Photometrie der Gestirne,* by G. Müller. Ap.J. 7, 311-315.
Notes on New Gases in the Earth's Atmosphere. Ap.J. 8, 121-122.
Review of: *The Sun's Place in Nature,* by Sir Norman Lockyer. Science N.S. 7, 777-778.

1899

The Variable Velocity of Polaris. Ap.J. 10, 184-185.
On Titanium for a Comparison Spectrum. Ap.J. 10, 207-208.
Corrections to Determinations of Absolute Wave-Length. Ap.J. 10, 283-285; Publ. As. and Ap. Soc. Am. 1, 95 (Abstract).
Review of: *Untersuchungen über die Spectra von 528 Sternen,* by H. C. Vogel and J. Wilsing. Ap.J. 10, 362-367.
Review of: *Comparative Photographie Speetra of Stars to the 3½ Magnitude; Spectra of Southern Stars,* by Frank McClean. Ap.J. 10, 367-369.
Notes on the Reduction of Stellar Spectra. Science N.S. 10, 845; Publ. As. and Ap. Soc. Am. 1, 94.

1900

Review of: *Publicationen des Astrophysikalischen Observatoriums zu Potsdam; Photographische Himmelskarte,* Band I. Ap.J. 12, 297-303.
Review of: *Strahlung und Temperatur der Sonne,* by J. Scheiner. Ap.J. 12, 303-305.
Spectroscopic Results Obtained at the Solar Eclipse of May 28, 1900. Ap.J. 12, 307-351.

1901

Nova Persei. A.J. 21, 104.
Notes on the Visual Spectrum of Nova Persei. A.J. 21, 114-115.
Review of: *An Atlas of Representative Stellar Speetra from λ 4870 to 3300,* by Sir William and Lady Huggins. Science N.S. 13, 222-224.
Review of: *Representative Stellar Spectra,* by Sir William Huggins. Science N.S. 13, 222-224.
Review of: *Astronomie Stellaire,* by C. H. André. Science N.S. 13, 618-619.

1902

The Bruce Spectrograph of the Yerkes Observatory. Ap.J. 15, 1-27; Science N.S. 15, 298-299 and Publ. As. and Ap. Soc. Am. 1, 178-179 (1910) (Abstracts).
The Spectroscopic Binary β Cephei. Ap.J. 15, 340-341.

Wave-Lengths of Certain Lines of the Second Spectrum of Hydrogen. Ap.J. 16, 100-105.

(With Walter S. Adams) Wave-Lengths of Certain Oxygen Lines. Ap.J. 16, 119-120.

Co-operation in Observing Radial Velocities of Selected Stars. Ap.J. 16, 169-177.

Review of: *Inorganic Evolution as Studied by Spectrum Analysis,* by Sir Norman Lockyer. Science N.S. 15, 584-586.

1903

(With Walter S. Adams) Five Stars Whose Radial Velocities Vary. Ap.J. 17, 150-153.

(With Walter S. Adams) Additional Stars of the Orion Type Whose Radial Velocities Vary. Ap.J. 17, 246-247.

(With Walter S. Adams) Two Stars with Variable Radial Velocities. Ap.J. 17, 381-382.

(With Walter S. Adams) Spectrographic Observations of Standard Velocity Stars (1902-1903). Ap.J. 18, 237-277.

(With Walter S. Adams) Ten Stars Whose Radial Velocities Vary. Ap.J. 18, 383-389.

1904

(With Walter S. Adams) Eight Stars Whose Radial Velocities Vary. Ap.J. 19, 151-155.

Review of: *Wellenlängen—Tabellen für spektralanalytische Untersuchungen, auf Grund der ultravioletten Funkenspectren der Elemente,* by Franz Exner and E. Haschek. Ap.J. 19, 302-304.

(With Walter S. Adams) Observations with the Bruce Spectrograph. Ap.J. 19, 350-356.

Radial Velocity of T Vulpeculae. Ap.J. 20, 296.

A Desideratum in Spectrology. Ap.J. 20, 342-346.

(With Walter S. Adams) Radial Velocities of Twenty Stars Having Spectra of the Orion Type. Publ. Yerkes Obs. 2, 145-249; The Chicago University Decennial Publs. 8, 143-250; Publ. As. and Ap. Soc. Am. 1, 184-185 (1903) (abstract); Science N.S. 17, 324-325 (1903) (abstract).

1905

Ernst Abbe. Ap.J. 21, 379-381.

(With Julius A. Brown) Wave-Lengths of Certain Silicon Lines. Ap.J. 22, 157-160.

Review of: *Index to the Literature of the Spectroscope (1887-1900),* by Alfred Tuckerman. Ap.J. 22, 162-163.

Spectrographic Observations of Certain Variable Stars. Ap.J. 22, 213-216.

Review of: *Lehrbuch der Physik,* Band II, by O. D. Chwolson. Ap.J. 22, 227-228.

Walter F. Wislicenus. Ap.J. 22, 345.

Review of: *Problems in Astrophysics,* by Agnes M. Clerke. Science N.S. 21, 574-576.

1906

Review of: *Beiträge zur Photochemie und Spectralanalyse,* by J. M. Eder and E. Valenta. Ap.J. 23, 171-173.

Review of: *Newcomb-Engelmann's Populäre Astronomie,* by H. C. Vogel. Ap.J. 23, 174-175.

Review of: *An Introduction to the Study of Spectrum Analysis,* by W. Marshall Watts. Ap.J. 23, 177-178.

Spectrographic Observations. Ap.J. 23, 264-269.

The Snow Fund of the Yerkes Observatory. Ap.J. 24, 219.

The Period of β Cephei. Ap.J. 24, 259-262.

Observations of Radial Velocities. Science N.S. 23, 449.

The Observations of Sun-Spots by the late C. H. F. Peters (note). Science N.S. 23, 452.

1907

Georges Rayet. Ap.J. 25, 53-54.

Nine Stars Having Variable Radial Velocities. Ap.J. 25, 59-65.

Heliographic Positions of Sun-Spots Observed at Hamilton College from 1860-1870, by C. H. F. Peters. Edited for publication by E. B. Frost. Carnegie Institution Publ. 43, 1-189.

Review of: *Sternverzeichnis enthaltend alle Sterne bis zur 6.5 ten Grösse für das Jahr 1900,* by J., R., and L. Ambronn. Ap.J. 25, 153-154.

1908

Hermann Carl Vogel. Ap.J. 27, 1-11.

Spectroscopic Binaries under Observation at Different Institutions. Ap.J. 27, 161-162, 166.

On Certain Spectroscopic Binaries. A.N. 177, 171-174.

Charles A. Young. Science N.S. 27, 136-139; J.Can.R.A.S. 2, 27-31.

Morehouse's Comet. Science N.S. 28, 379.

1909

(With J. A. Parkhurst) Spectrum of Comet Morehouse (1908*c*). Ap.J. 29, 55-64; Science N.S. 29, 36-37 (Abstract).

Review of: *The Theory of Optical Instruments,* by E. T. Whittaker. Ap.J. 29, 90-91.

Review of: *The World Machine: The Cosmic Mechanism,* by Carl Snyder. Ap.J. 29, 92-93.

Review of: *Annales de la Faculté des Sciences de Marseille.* Tome XVII, Fascicule 3, 1908, by M. M. Buisson and Fabry. Ap.J. 29, 95-96.

Spectrographic Notes. Ap.J. 29, 233-239.

(With Oliver J. Lee) Eight Stars Having Variable Radial Velocities. Ap.J. 30, 62-67.

Review of: *Formeln und Hilfstafeln für geographische Ortsbestimmung,* by Th. Albrecht. Ap.J. 30, 321.
Review of: *Tafeln für numerisches Rechen mit Maschinen,* by O. Lohse. Ap.J. 30, 321-322.
Charles Augustus Young. Ap.J. 30, 323-338.

1910

Review of: *A General Index to Sidereal Messenger, Astronomy and Astrophysics, Popular Astronomy,* by W. W. Payne. Ap.J. 31, 184.
Review of: *Annuaire Astronomique de l' Observatoire Royal de Belgique,* by Professor Stroobant. Ap.J. 31, 184.
Review of: *Spectroscopic Astronomique,* by P. Salet. Ap.J. 31, 279-280.
Review of: *Annuaire pour l'an 1910 publie par le bureau des longitudes;* Paris: Gauthier Villars, 1909. Ap.J. 31, 280.
Note on the Accuracy of Radial Velocity Determinations. Ap.J. 31, 377-381.
Review of: *The Moon in Modern Astronomy,* by Philip Fauth. Ap.J. 31, 383.
Corrections to Radial Velocities of Certain Stars of the Orion Type. Ap.J. 31, 430-432.
Notice of the Death of Sir William Huggins. Ap.J. 31, 463.
(With J. C. Kapteyn) On the Velocity of the Sun's Motion through Space as Derived from the Radial Velocity of Orion Stars. Ap.J. 32, 83-90; Errata 33, 86.
Review of: *Die Einheit des physikalischen Weltbildes,* by Max Planck. Ap.J. 32, 325-326.
Review of: *Acht Vorlesungen über theoretische Physik,* by Max Planck. Ap.J. 32, 325-326.
The International Union for Co-operation in Solar Research. Ap.J. 32, 258-261.
Review of: *The Scientific Papers of Sir William Huggins,* by Sir William and Lady Huggins. Ap.J. 32, 323-325.
Review of: *The Spectroscope and its Work,* by H. F. Newall. Ap.J. 32, 402-403.
Charles Augustus Young. Biogr. Mem. Nat. Ac. Sc. 7, 89-114.
Corrections to Determinations of Absolute Wave-Lengths. Publ. As. and Ap. Soc. Am. 1, 95.
(With Walter S. Adams) New Spectroscopic Binaries. Publ. As. and Ap. Soc. Am. 1, 186.
Burnham's Forthcoming General Catalogue of Double Stars. Publ. As. and Ap. Soc. Am. 1, 241.
Observations of Radial Velocities. Publ. As. and Ap. Soc. Am. 1, 243-244.
The Observations of Sun-Spots by the late C. H. F. Peters. Publ. As. and Ap. Soc. Am. 1, 248.
Spectroscopic Observations of Stars. Publ. As. and Ap. Soc. Am. 1, 271.
Spectrographic Observations. Publ. As. and Ap. Soc. Am. 1, 308-309.

Lack of Spectroscopic Evidence of a Dispersion of Light in Space. Publ. As. and Ap. Soc. Am. 1, 324.

1911

Review of: *Newcomb-Engelmann's Populöre Astronomie,* by P. Kempf. Ap.J. 33, 187-189.

On the Classification of Stellar Spectra. Ap.J. 33, 273-277.

Review of: *Transoctions of the Internotional Union for Co-operotion in Solor Research,* edited by A. Schuster. Ap.J. 33, 301-302.

Observations of Nova Lacertae at the Yerkes Observatory. Ap.J. 33, 410-417.

Nova Lacertae of 1910. P.A. 19, 111-112.

The Contribution of Astronomy to General Culture. P.A. 19, 463-471.

Radial Velocity of Halley's Comet as Derived from a Spectrogram. P.A. 19, 558-559; Publ. As. and Ap. Soc. Am. 2, 69 (1915).

Review of: *Rodial Veloeities of 150 Stars South of Declinotion—20° Determined by the D. O. Mills Expedition, Period 1903-1906.* Publ. A.S.P. 23, 257-260.

1912

The Astronomical and Astrophysical Society. Ap.J. 35, 144-145.

On the Spectrum of P Cygni. Ap.J. 35, 286-293.

Review of: *Tronsactions of the Internationol Union for Co-operotion in Solor Research.* Ap.J. 35, 294.

Review of: *The Progress of Physics During 33 Yeors (1875-1908),* by Arthur Schuster. Ap.J. 35, 295.

Review of: *The Collected Seientific Works of Sir Williom Hersehel.* Ap.J. 35, 296-297.

Review of: *Descriptive Meteorology,* by Willis L. Moore. Ap.J. 35, 297-299.

Review of: *The Great Star Mop,* by H. H. Turner. Ap.J. 35, 299.

Review of: *Stor Lore of All Ages,* by William Tyler Olcott. Ap.J. 35, 299-300.

Review of: *Tables of Physieal and Chemicol Constonts ond Some Mathemoticol Functions,* by G. W. C. Kaye and T. H. Laby. Ap.J. 35, 300.

Preliminary Note of the Sun's Velocity with Respect to the Stars of Spectral Type A. Mem. Spettr. It. (2), 1, 26-28.

1913

The Spectroscopic Determination of Stellar Velocities Considered Practically. P.A. 21, 189-207.

Measurement of the Heat Received from the Sun. P.A. 21, 468-472.

Review of: *Stellor Motions,* by W. W. Campbell. Publ. A.S.P. 25, 277-283.

1914

Review of: *Annuaire Astronomique et Météorologique pour 1914*, by Camille Flammarion. Ap.J. 40, 160.

(With Frances Lowater) Stellar Wave-Length of λ 4686 and Other Lines in the Spectrum of 10 Lacertae. Ap.J. 40, 268-273.

Note on Two Spectroscopic Binaries. P.A. 22, 12-13.

(With Harold L. Alden) Objective-Prism Spectra of Nebulae Examined with the Stereocomparator. P.A. 22, 136-137; Publ. Am. Astr. Soc. 3, 8-9.

Spectrographic Observations. P.A. 22, 568.

The Spectral Line 4686 (Note). The Observatory 37, 261.

Belgian Professors and Scholars (Note). Science N.S. 40, 522.

1915

Julius Scheiner. Ap.J. 41, 1-9.

Review of: *Reform of the Calendar*, by Alexander Philip. Ap.J. 41, 172.

Spectroscopic Binary in the Trapezium of Orion. P.A. 23, 361-362.

(With Charles A. Maney) New Conceptions of the Nebula of Orion. P.A. 23, 485-487.

(With Oliver J. Lee) Items as to New Spectroscopic Binaries. Publ. As. and Ap. Soc. Am. 2, 9.

Radial Velocities within the Great Nebula of Orion. Proc. Nat. Ac. Sc. 1, 416.

1916

Note to: Summary, arranged according to Spectral Classes, of the Radiometric Measures on 110 Stars made by Dr. W. W. Coblentz with the Crossley Reflector at Lick Observatory. P.A. 24, 136-138.

The Future of International Science. Observatory 39, 435-436.

1917

Review of: *Astronomischer Jahresbericht*, Band XV, XVI, XVII; Kg. Rechen-Institut. Ap.J. 45, 356-357.

The Meteor of February 5, 1917. P.A. 25, 253-255.

Introductory note to: Stellar Parallaxes derived from Photographs made with the Forty-Inch Refractor, by F. Slocum, S. A. Mitchell, O. J. Lee, A. H. Joy, and G. Van Biesbroeck. Publ. Yerkes Obs. 4, Part I, 1-2.

1918

The Observatory of Poulkova. Ap.J. 47, 139-140.

The Radial Velocity of 2 ω Leonis. Ap.J. 48, 258-260.

Preliminary Note on 66 Eridani. Ap.J. 48, 260.

The Total Solar Eclipse of 1918, June 8: a Reconnaissance. P.A. 26, 103-110.

Useful Observations at Observatories and Laboratories Outside the Zone of Totality, June 8, 1918. P.A. 26, 297-299.

Total Solar Eclipse, June 8, 1918. P.A. 26, 458-462.

Usefulness of a "Movie" Camera for Photographing Phenomena of Solar Eclipses (Abstract). P.A. 26, 697-698; Publ. Am. Astr. Soc. 4, 22-23 (1923).

(With J. A. Parkhurst) The Spectrum of Nova Aquilae on June 8, 9, 10, 1918 (Abstract). P.A. 26, 698; Publ. Am. Astr. Soc. 4, 23 (1923).

Early Observations of Nova Aquilae on June 8. P.A. 26, 723-724.

What Might Have Happened. P.A. 26, 724.

Spectrographic Observations. Publ. Am. Astr. Soc. 3, 81.

Spectroscopic Investigation. Science N.S. 47, 416-417.

Valuable Results Obtained by the Yerkes Observatory Solar Eclipse Expeditions. Monthly Eve. Sky Map 12, No. 141 (September).

1919

A Star with Disappearing Bright Lines. Ap.J. 49, 61-62.

Review of: *Science and Learning in France, with a Survey of Opportunities for American Students in French Universities: An Appreciation by American Scholars,* by John H. Wigmore, Editor-in-Chief. Ap.J. 49, 63-64.

Results of Observations of the Eclipse by the Expedition from Yerkes Observatory. Proc. Am. Phil. Soc. 58, 282-288.

Stellar Spectra. Monthly Eve. Sky Map 13, No. 145 (January).

1920

Review of: *Advanced Lecture Notes on Light,* by J. R. Eccles. Ap.J. 51, 128.

Note to accompany spectrograms of Nova Cygni No. 3 taken with the Bruce Spectrograph of the Yerkes Observatory. P.A. 28, 531-532; Publ. Am. Astr. Soc. 4, 156-157 (1923).

How the Sun's Rotation is Determined (Note). Monthly Eve. Sky Map 14, No. 168 (December).

1921

Sherburne Wesley Burnham, 1838-1921. Ap.J. 54, 1-8.

Sherburne Wesley Burnham, 1838-1921. J.Can.R.A.S. 15, 269-275; Science N.S. 53, 373-377.

β—The Chicago University Record N.S. 7, 117-123.

(With J. A. Parkhurst) Objective Prism Spectra of Nova Aquilae 3 and Nova Cygni 3. P.A. 29, 224-225; Publ. Am. Astr. Soc. 4. 224-225.

A Family of Astronomers. P.A. 29, 536-540.

(With S. B. Barrett) Comments on the Spectrum of Nova Cygni No. 3 and Nova Aquilae No. 3. P.A. 29, 149-150; Publ. Am. Astr. Soc. 4, 209 (1923).

On Some "Irreconcilables" Among Stellar Radial Velocities. P.A. 29, 158-159; Publ. Am. Astr. Soc. 4, 217-218 (1923).

Introduction to: *The Rotation Period of the Sun,* by Philip Fox. Publ. Yerkes Obs. 3, Part III.

1922

Relief for Russian Astronomers. Science N.S. 56, 279-280.

The Yerkes Observatory of the University of Chicago. Monthly Eve. Sky Map 16, No. 186 (June).

1923

Edward Emerson Barnard. Ap.J. 58, 1-35.

Note on the Total Eclipse of September 10, 1923. Ap.J. 58, 263-264.

(With Frances Lowater) Spectrographic Observations of Mira Ceti, R Leonis, T Cephei, and R Serpentis. Ap.J. 58, 265-279.

Review of: *Newcomb-Engelmann's Populäre Astronomie,* Sechste Auflage, edited by H. Ludendorff, with the collaboration of G. Eberhard, E Freundlich, and A. Kohlschütter. Ap.J. 58, 314-315.

Regarding Beta Ceti. P.A. 31, 289-290.

A Retrospect of Twenty-Five Years. Univ. Chicago Record N.S. 9, 24-35.

Edward Emerson Barnard. Univ. Chicago Record N. S. 9, 121-132.

Report on Parallaxes. Publ. Am. Astr. Soc. 4, 67-68.

Visualized Astronomy. Visual Education 4, 43-46, 83-86, 94.

1924

Review of: *Handbuch der Spectroscopie,* by H. Kayser and H. Konen. Ap.J. 59, 192-194.

Review of: *Verhandelingen van Dr. P. Zeeman over Magneto-Optische Verschijnselen.* Ap.J. 59, 194-196.

Review of: *L'Astronomie et les Astronomes,* by Auguste Collard. Ap.J. 59, 196.

Ernest Fox Nichols. Ap.J. 59, 260.

(With Otto Struve) The System of 61 μ Orionis. Ap.J. 60, 192-200.

(With Otto Struve) Orbit of Spectroscopic Binary 66 Eridani. Ap.J. 60, 313-318.

Fourteen Spectroscopic Binaries. Ap.J. 60, 319-320.

The Expedition from the Yerkes Observatory for Observing the Total Solar Eclipse of September 10, 1923, at Camp Wrigley. P.A. 32, 205-217.

The Transit of Mercury. P.A. 32, 390.

The Structure of the Cosmos. Contributions of Science to Religion, by Shailer Mathews. Chapter 4, 58-104. D. Appleton and Company, New York and London.

The Heavens are Telling. Pamphlet 1-31. Published by the American Institute of Sacred Literature, Chicago, September.

1925

Review of: *Astronomie,* edited by J. Hartmann. Ap.J. 61, 205-206.

Review of: *Observations of the Total Solar Eclipse of January 24, 1925, made by Electric Companies affiliated with the Consolidated Gas Company of New York.* Ap.J. 61, 207.

John Adelbert Parkhurst. Ap.J. 61, 454.

Tentative Plans for the Observation of the Total Eclipse by Members of the Staff of Yerkes Observatory. P.A. 33, 12-14; 213 (Note).

Short Eclipse Notes. P.A. 33, 213.

Obituary of John A. Parkhurst. A.N. 224, 147-148.

Spectroscopic Observations of the Eclipse of January 1925 (Note). Science N.S. 61, 41.

1926

(With Storrs B. Barrett and Otto Struve) Radial Velocities of 368 Helium Stars. Ap.J. 64, 1-77; Proc. Nat. Ac. Sc. 12, 283-285 (Abstract).

1927

Review of: *Die Kultur der Gegenwart,* Dritter Teil, Dritte Abteilung: Physik, edited by E. Lecher. Ap.J. 65, 131-132.

Review of: *Fundamental Concepts of Physics,* by Paul R. Heyl. Ap.J. 65, 132.

Carl Runge. Ap.J. 65, 200.

The Barnard Atlas of Selected Regions of the Milky Way. P.A. 35, 486-487; Publ. Am. Astr. Soc. 6, 24-25 (1931).

Biographical Memoir of Edward Emerson Barnard, 1857-1923. Mem. Nat. Ac. Sc. 21, 1-23.

Introduction to: Zone + 45° of Kapteyn's Selected Areas: Photographic Photometry for 1450 Stars, by J. A. Parkhurst. Publ. Yerkes Obs. 4, Part VI (1927).

Preface to: A Photographic Atlas of Selected Regions of the Milky Way, by E. E. Barnard—edited by Edwin B. Frost, Director, and Mary R. Calvert, Assistant. Carnegie Institution of Washington.

1928

The Department of Astronomy and Astrophysics. Univ. Chicago Record N.S. 14, 52-56.

1929

Review of: *Annual Tables of Constants and Numerical Data,* by Permanent International Committee. Ap.J. 69, 75-76.

(With Storrs B. Barrett and Otto Struve) Radial Velocities of 500 Stars of Spectral Class A. Publ. Yerkes Obs. 7, Part I, 1-79.

The Magnificent Universe; an Impression of the New Ideas in the Light of Recent Investigations. Century Magazine (March), 590-598.

1930

Note on Barnard's unpublished Observations of Comets. A.J. 40, 99.

1931

Micrometer Measures of Star Clusters, by E. E. Barnard. Edited by E. B. Frost, etc. Publ. Yerkes Obs. 6, Part I, 1-106.

1932

Review of: *Johannes Kepler Festschrift*, Teil I, by Dr. Karl Stöckl. Ap.J. 75, 275-276.

Review of: *Annual Tables of Constants and Numerical Data*, by Permanent International Committee. Ap.J. 75, 371-372.

Review of: *Données Numériques de Spectroscopie*, by Permanent International Committee. Ap.J. 75, 371-372.

Review of: *Les Observatoires Astronomiques et les Astronomes*, by P. Stroobant and Associates. Ap.J. 76, 83-84.

Eclipse Report, August 31, 1932. P.A. 40, 474.

(With Otto Struve and C. T. Elvey) A Study of the Spectrum of 7 ε Aurigae. Publ. Yerkes Obs. 7, Part II, 1-52.

1933

An Astronomer's Life. Houghton Mifflin Company, Boston and New York, 1-300.

1935

Let's Look at the Stars. Houghton Mifflin Company, Boston and New York, 1-115.

Reports of the Director of the Yerkes Observatory

Publ. Am. Astr. Soc. 5, 135-138 (1922-1923); P.A. 32, 164-167 (1924).
Publ. Am. Astr. Soc. 5, 241-244 (1923-1924); P.A. 33, 117-121 (1925).
Publ. Am. Astr. Soc. 5, 340-344 (1924-1925); P.A. 34, 118-122 (1926).
Publ. Am. Astr. Soc. 5, 445-450 (1925-1926); P.A. 35, 108-114 (1927).
Publ. Am. Astr. Soc. 6, 77-82 (1926-1927); P.A. 36, 180-185 (1928).
Publ. Am. Astr. Soc. 6, 206-210 (1927-1928); P.A. 37, 159-163 (1929).
Publ. Am. Astr. Soc. 6, 325-329 (1928-1929); P.A. 38, 349-353 (1930).
Publ. Am. Astr. Soc. 6, 419-422 (1929-1930); P.A. 39, 272-275 (1931).
Publ. Am. Astr. Soc. 7, 81-86 (1930-1931).
Publ. Am. Astr. Soc. 7, 161-167 (1931-1932).

Brief Notes Concerning the Yerkes Observatory

P.A. 27, 130-131 (1918).
P.A. 28, 118-121 (1919).
P.A. 28, 563-564 (1920).
P.A. 29, 595-596 (1921).
P.A. 32, 585 (1924).
P.A. 34, 659 (1926).
P.A. 38, 571-572 (1930).

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OF

HENRY FAIRFIELD OSBORN

1857-1935

BY

WILLIAM K. GREGORY

PRESENTED TO THE ACADEMY AT THE AUTUMN MEETING, 1937

HENRY FAIRFIELD OSBORN

1857–1935

BY WILLIAM K. GREGORY

Henry Fairfield Osborn was born at Fairfield, Connecticut, August 8, 1857, the second child and eldest son of William Henry Osborn and Virginia Reed Osborn, née Sturges, both of New England stock. The early American Osborns are recorded in several Massachusetts towns, particularly in Salem. The Sturges family had "lived for generations" in Fairfield, Connecticut. One of his mother's ancestors, the Reverend Ebenezer Pemberton, a prominent divine, was a founder of the College of New Jersey (Princeton University). His maternal grandfather, Jonathan Sturges, was a prominent merchant in New York.

His father, although the son of a man of property, had left school at an early age and entered an East Indian trading house in Boston. Sent as their representative to Manila, he was soon in business there for himself. Later he was connected with the Illinois Central Railroad and eventually became its long-term president, engineering it through the panic of 1857 and gradually building up a considerable fortune.

It will be noted that Henry Fairfield Osborn was born in the year of the great panic and four years before the beginning of the Civil War. Although he received his middle name from the town of his mother's ancestors, his parents lived for the most part in New York City, where they were among the "first families."

Henry Fairfield attended the Columbia Grammar School in New York City, where, according to his own recollections, the discipline was rigid.

The summer home of the family was at Garrison, N. Y., near the base of a mountain in the highlands of the Hudson River. There he and his brothers rode and walked along the mountain paths. One of his brothers, who was drowned in the Hudson River near Garrison while still a youth, had made a collection of local birds which was later presented to the American Museum of Natural History in New York. Henry Fairfield, however, unlike most boys who became famous naturalists, does not

appear to have been a "born collector" of insects, rocks, plants or animals. Nor do we hear of his doing other things that implied the patient acquisition of manual skill. His greatness was to be developed in a quite different way.

Later his father built a new and greater mansion on the summit of the same mountain, overlooking the Hudson River, opposite West Point. It would be hard to find anywhere a more delightful view of placid river and rounded mountains than that which is seen from the gray towers of "Castle Rock." Up the winding road to this castle came many American and foreign guests, including men and women who were eminent in science, literature, art and education. But whether at Garrison or in New York City, Henry Fairfield lived in a highly selective social environment which was in many essentials similar to that of the English upper classes; this environment doubtless prepared him in part for his later successful relations with his English friends and colleagues; it also helped to develop the quality of leadership, which was of the utmost importance in his life.

William Henry Osborn gave his sons every advantage and was ready to help them at critical times, yet he took care to train them in habits of industry and self reliance. Thus he encouraged Henry Fairfield, when the latter was a shy and retiring youth of fourteen years, to start "The Boys' Journal", of which thirteen numbers were published. The boy and his fellows prepared the copy, set up and printed the magazine. In his old age Osborn spoke of this experience as a great training in self reliance.

In commenting on the present biographical memoir, Professor Osborn's brother, Mr. William Church Osborn, under date of August 5, 1937, writes as follows:

"His father took a very liberal view of my brother's scientific work and encouraged him in it as far as he could and I think he had him take a year in an office to give him some business experience. He built for my brother the Woodsome Lodge at Castle Rock in which my brother did a large part of his creative work. I think the most important part though was his own example as a persistent, hard-working, hard-driving man of affairs, coupled with an unusual breadth of view on the problems

of the time. I think his example had a great effect on my brother's life."

Henry Fairfield's mother, Virginia Sturges Osborn, was a woman of genuine piety and humanity, who took a prominent part in works of charity and devotion in New York. Concerning the influence of Osborn's mother upon her son, his brother, William Church Osborn, in answer to an inquiry from the Reverend Henry S. Coffin, wrote as follows (December 3, 1935):

"I like to think that the 'long background which explains a man's view' was, in my brother's case, the deeply religious nature of my mother and the training which she gave my brother both by precept and example. She gave a great deal of time to him through his boyhood and said to me once that he was 'the child of many prayers'. I never talked with him on these subjects but my feeling is that with a religious spirit inherited from his mother and his grandfather, Jonathan Sturges, he had the added force of the precept and example of his mother during his formative years."

From the personal influence of both his parents he doubtless derived somewhat of his sincerity and directness, his lack of guile, his urbanity, his loyalty in friendship and his appreciation of loyalty in others. And under the guidance of his parents and teachers, his pastors and friends, he absorbed many of the best features of the religious and social environments of New England, of the "Old New York" families and of the Scotch Presbyterians.

AT PRINCETON

After being prepared for Princeton at the Collegiate Institute in New York, he became a student at that ancient stronghold of democracy and Presbyterianism in the days of the famous Dr. McCosh. A number of the essays of his senior year are preserved. His handwriting at this period was close to its definitive and nearly constant form, which was later described by a French colleague as *"le main magistral de M. Osborn."* If he had ever struggled with timidity and an inferiority complex, if he had ever had occasion to regret impetuous actions, this ponderous handwriting, with its deliberate and very distinguished letters,

its implied earnestness and sincerity, suggests that he had himself well in hand.

One of his essays of this period includes an attempted refutation of the "atheists' argument" that an all-wise and benevolent God would never have permitted evil in the world nor have condemned multitudes of the poor creatures of his own hand to a burning hell. His argument in brief is that, for reasons unknowable to mortals, salvation can be attained only by unceasing effort; this indeed was the theme of his life.

Dr. McCosh knew well not only how to inspire respect for religion in his students but even how to reconcile religion and science. It is said that he was the first Presbyterian divine in America to accept evolution as God's method of creation. And his pupil Henry Fairfield Osborn defended the same thesis. Dr. McCosh was essentially a religious philosopher and teacher, concerned with the relations of mind and matter and the problem of man's origin, fall and redemption. He had a great part in making Osborn also primarily a philosopher and teacher who consistently fought for "idealism" in opposition to "materialism" of the type exemplified by Ernst Haeckel.

As to the sources of his own scientific career, Osborn, in his frank and sincere autobiography,[1] tells us that "throughout this exposition [of his fifty-two years of activity in different fields of science] there is no indication of a predisposition on my part to this life of research; in my school and early life I was never conscious of such a predisposition nor am I able in a review of my ancestry and of my own boyhood to account for my life vocation. My boyhood and youth were similar to those of almost any other boy, undistinguished by a display of the driving force which from the moment of its awakening in the junior year of my Princeton days, has ever impelled me with constantly increasing power. The impulse which led me to dedicate my life to research must truly have come from within. . . . Thus, except for a few early statistics, my biography actually begins with the first call to biology and geology."

This passage reflects, even though indirectly, his life-long leanings toward predetermination, especially by heredity, his

[1] "Fifty-two Years of Research, Observation and Publication: 1877-1929," p. 151.

belief in "creative evolution," in a somewhat mystical sense, and his strong disbelief in "chance" as a factor in personal history.

A more pragmatic account of the young Osborn's "first call" to a life of science has been given in detail by his partner, Professor W. B. Scott. The gist of the matter was that three students in Professor Guyot's geology course, H. F. Osborn, W. B. Scott, and Francis Speir, Jr., determined not to let Yale University have a monopoly in fossil-hunting expeditions in the West. They wisely began by making a preliminary geological reconnaissance of the Highlands of the Hudson River. When Osborn was twenty years old they initiated and carried to a successful conclusion the "Princeton Scientific Expedition of 1877." Under the direction of Professor Kargé, they made collections of fossil fishes and plants in Colorado and of fossil mammals in the Eocene formation near Fort Bridger.

During the ensuing year, as graduate students in the E. M. Museum of Geology and Archaeology, they worked the fossils out of the matrix, searched the reports already published by Leidy, Cope and Marsh, compiled a systematic catalogue of the Eocene Vertebrates of Wyoming, made the drawings and wrote the descriptions of the new material.

In their letter of transmittal of the report[2] to Professor Arnold Guyot, Director of the E. M. Museum of Princeton, they observe:

"Now that the present work is ready for the press, we are very sensible that it must contain errors, which, while they have escaped our notice, will be readily detected by eyes more experienced. These, we trust, will be excused when it is remembered that we are just entering a field which others have explored for years, and opening a work which Princeton, with her many other lines of study, has never hitherto attempted." They also express their "gratitude to Professors Leidy and Cope for their generous aid, both in the way of advice and of material put in our hands for comparison." Thus began the friendly relations with Professors Leidy and Cope, which were to be of great aid to the young palaeontologists in the years to come.

[2] "Palaeontological Report of the Princeton Scientific Expedition of 1877," by Henry F. Osborn, Wm. B. Scott, and Francis Speir, Jr. Contrib. E. M. Mus. Geol. and Archaeol. of Princeton College, No. 1. 1878.

The plates illustrating the report were based on original drawings, mostly by Osborn. They reveal high ability to grasp and record the subtle contours of fossil bones and teeth.

The fossil mammals described represented families upon which Osborn and Scott later spent years of research. There were primates, creodonts or archaic carnivores, perissodactyls, artiodactyls, amblypods, and rodents. Some of them, like *Orohippus,* pointed toward modern families; others, such as *Palaeosyops,* belonged to wholly extinct groups. Thus, Osborn and Scott, together with several of their classmates, made their entry into a world of powerful enchantment, a world which laid such a spell upon them that they were inspired to go back to it again and again.

We find Osborn leading a second Princeton expedition to Wyoming in the following summer (1878) and, in company with Messrs. McMaster, Scott, Speir, McCosh and Annin, exploring the Upper Eocene beds of the Washakie Basin. Here they discovered much valuable material of Professor Cope's *Loxolophodon* and allied genera. These strange beasts had feet like those of elephants but long narrow skulls surmounted by three pairs of blunt horns. They had great sabre-like upper canine teeth and their cheek teeth bore oblique cross-crests adapted for cutting coarse vegetation.

Other important fossils were discovered which were also described later by Osborn [3] and Scott and Osborn. On this expedition the explorers paid more particular attention to the stratigraphic sequence of the Eocene formations of Wyoming and to the problems involved in determining and correlating the corresponding formations in different areas.

Thus we suspect that the mysterious "impulse" and "call" to a life of research which Professor Osborn envisioned in his later years may have been not a sudden "creative evolution" but a gradual summation of his own reasoned responses to favorable environmental stimuli and opportunities.

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[3] E.g., "A Memoir upon *Loxolophodon* and *Uintatherium.*" Contrib. E. M. Mus. Geol. and Archaeol., College of New Jersey, vol. I, no. 1, 1881.

See also Contrib. E. M. Mus. Geol. and Archaeol. Princeton College, Bull. No. 3, 1883.

Not yet, however, was Palaeontology a potent word in the curriculum of the College of New Jersey. Biology, on the other hand, was just beginning to acquire its magic. In short, Dr. McCosh, with his broad philosophy, saw that there was room for both Scott and Osborn in that department. They in turn had realized their own lack of adequate preparation in biology and their need of direct contact with the science that had been so recently rejuvenated by Darwin. What more natural than that they should plan a year of study in Europe? Meanwhile, in the winter of 1878 Osborn [4] took a special course of study in anatomy and histology in the College of Physicians and Surgeons and Bellevue Medical School of New York under Dr. William H. Welch, who later became famous at Johns Hopkins University.

In April, 1879, Osborn went to Cambridge University, England,[5] and there joined Scott in a three months' study of embryology under Francis Balfour. In the Morphological Laboratory at Cambridge, Balfour supervised the studies of the young Americans upon certain developmental stages of the common European newt.[6] This study must have been completed within a few months of its inception, for it was published in October of the same year. Taking the plans and descriptions followed on the one hand by Balfour in his account of the embryology of sharks, and on the other hand by Götte in his description of the development of the toad (*Bombinator igneus*), the authors dealt in a strictly comparative way with the segmentation and formation of the three germ layers, the origin of the notochord, the body cavity, somites of the head, etc. The plates were made from drawings by the authors.

The summer of 1879 Osborn spent in Germany [5] and the winter of 1879-80 in London, studying comparative anatomy at the Royal College of Science under Professor T. H. Huxley. This was in many ways a period of signal importance to his future career. From every one of his great teachers he derived inspiration, perspective, insight and method.

[4] "Fifty-two Years of Research, Observation and Publication," p. 153.
[5] "After Twenty Years": The Record of the Class of 1877, Princeton University, 1877-1897, p. 72. Trenton, N. J. 1898.
[6] Quar. Journ. Micros. Sci., vol. XIX, N. S. London, 1879.

While his Princeton and home connections gave him an introduction into the best social and university circles, he and his partner Scott were likewise welcomed as young explorers of the fossil treasures of western North America. And we can well imagine how deeply the sensitive young Osborn must have been moved when Professor Huxley, conducting Charles Darwin through the laboratory of comparative anatomy in London, stopped and presented the young American to that incomparably great and gentle man. On this and succeeding periods in England he not only formed friendships of great value, with Professor Huxley, with Francis Galton, Edward B. Poulton, Leonard Darwin, and many others, but also acquired an abiding interest in the grand problems of evolution.

Returning to Princeton in the autumn of 1880, Osborn [7] was appointed to a special Biological Fellowship. In 1881 he received the degree of Sc.D. and was made Lecturer in Biology, then Assistant Professor and finally Professor of Comparative Anatomy.

During the twelve years of his service at Princeton his scientific publications, which were few and small in comparison with those of his later years, dealt mostly with topics in mammalian palaeontology, in comparative neurology and in certain limited studies of the "mind's chamber of imagery," due to connections with Dr. McCosh.

In the earlier years he frequently read papers at the Science Club at Princeton, some of which are preserved [8] in manuscript form. One of them is a brief unpublished account of a journey that he made shortly after his return from England to the coastal lands of Texas and Louisiana to collect materials for his and Scott's studies on the development of the Amphibia and Reptilia and for his own studies on the evolution of the brain. The country over which he travelled on horseback and by coach abounded in interest to the young naturalist: here ancient amphibians lived and bred, alligators laid their eggs, covered them in mounds and left diverse footprints on the muddy banks; here ganoid fishes of vast antiquity left their scales and bones in the

[7] "After Twenty Years": The Record of the Class of 1877.

[8] In the Osborn Library of the American Museum of Natural History, New York.

mud; here, in short, the story of past ages was being reenacted before his eyes.

Nevertheless he seems to have regarded this journey as unsuccessful. "Balfour's inspiration in embryology," he tells us,[9] "led to unsuccessful journeys and attempts in the southern United States to secure the embryonic history of two very characteristic American types, namely, the alligator and the giant long-tailed amphibians *Amphiuma* and *Menopoma*—unsuccessful because I had not the aptitude of the field naturalist in collecting these eggs and embryos nor a talent in embryological technique. It is well to realize one's inaptitudes, so that one may the better advance in the direction in which his talent does lie. *If you cannot find your research way in one direction turn to another in which you may be successful.*"

Whether or not he was justified in being discouraged and in believing that he "had not the aptitude of the field naturalist in collecting these eggs and embryos nor a talent in embryological technique," this state of mind may have disposed him to withdraw from comparative embryology and devote more time to fossil mammals; the latter by 1888 had practically crowded out his further work in the former field.

Here again we see in his history no signs of "predestination," hereditary or otherwise, but chiefly a wise opportunism and adaptability, a realization of his limitations in certain directions and a growing copiousness of production along the lines which suited him best.

By the time Osborn returned from England, after his contacts with Balfour and Huxley, he had a perfectly clear field of major interest, which was the study of evolution from as many angles as possible. Accordingly he pushed forward his studies on the foetal membranes of the opossum and other marsupials (1883, 1887) and upon the structure and evolution of the brain in amphibians (1883-1886). He was never content merely to describe facts but sought always for results of general interest. In this connection, in his autobiographic sketch (p. 63) he writes as follows:

"In every field of nature direct observation with accumulation

[9] "Fifty-two Years of Research, Observation and Publication," p. 65.

of facts is a fascinating pursuit. Many most useful and even eminent naturalists spend their entire lives in this way; they are the 'drawers of water and hewers of wood' for others. It is not that they lack powers of generalization but that they apparently take no interest in generalization for the drawing of inductions. Sometimes important discoveries are made in this methodical way but more often discovery of new principles emerges from generalization. In any event, the *discovery of new principles is the chief end of research.* As Darwin observed, the true naturalist is not content with merely assembling facts; his chief desire is to seek interpretations and explanations —in other words, to discover new principles.

"I have myself always found the mere assemblage of facts an extremely painful and self-denying process and I have always been animated by the hope that such dry work would finally be rewarded by an interpretation or the discovery of a new principle."

In the same revealing source book (p. 65) he sums up his work on the internal structure of the amphibian brain in the following passage:

". . . From personal experience also I discovered a very important principle in the internal structure of the amphibian brain (1888), namely, *the subdivision of the cranial nerves into many separate physiological components,* which in these very small brains could be traced with great distinctness, so that the older classification of the cranial nerves could be amplified by the newer classification based upon the many separate components.

"This near vista awaited the masterly patience and technique of one of my students, Oliver S. Strong, now Professor of Neurology in Columbia University, in a classic memoir on the brain of the frog, in which all the components of the cranial nerves were skillfully traced. A similar classic on the brain of the fish was also prepared by C. Judson Herrick, of the University of Chicago, under Strong's direction. My ten-year experience in comparative anatomy and neurology thus gave me the privilege of initiating a new school of neurological research in America, in which I myself saw the Promised Land in the

distance, although my technical disability and preoccupation with other interests precluded my attaining it."

His search for the origin of the mammalian corpus callosum led him to conclude (1886) that this structure was already foreshadowed in the brains of amphibians, but later neurologists [10] were able to prove that the corpus callosum arose only in the mammals above the grade of the monotremes.

In his work on the embryonic membranes of the opossum, "Osborn's only serious error seems to have been his identification of actual 'villi' on the outer surface of the chorion (subzonal membrane) in the region where the yolk-sac comes into apposition to its inner surface. These 'villi' have not been observed by any one else, and it seems almost certain that they were mere blister-like artifacts. In Osborn's 1883 paper he does not speak of these villi as already vascular but conjectures that they later become so. (He was misunderstood on the point by Haddon in his *Introduction to Embryology,* 1887.) The material on which Osborn's 1883 paper was based was very limited; only one pregnant opossum, and one horn of the uterus with the contained embryos was accidentally lost. His observations on the vascularity of the yolk-sac and his suggestion of its importance as the chief organ of nutrition during intrauterine life of the embryos are highly important, and he speaks of the structures as 'yolk-sac placentae' " (J. H. McGregor).

"Osborn thought, apparently erroneously, that the *cavity* of the yolk-sac in *Didelphys,* between the inner vascular surface and the outer non-vascular surface, became obliterated. This is certainly not the case in other marsupials" (J. H. McGregor).

Continuing his fruitful partnership with Scott, he published several papers (1882-1887) on Eocene ungulates, culminating in the account (1887) of the fossil mammals of the White River formation. In this paper the authors briefly described several new species of certain giant extinct ungulates that were allied with Dr. Leidy's *Titanotherium,* Cope's *Symborodon* and Marsh's *Brontotherium.* At this time doubtless Osborn began to be interested in the confusing taxonomic problem of this strange family (afterward referred to as the "titanotheres"),

[10] Elliot Smith and others.

which was to occupy so many years of research at a later period.

In 1886 Osborn made an extended visit in England in order to study the remains of Mesozoic mammals, chiefly in the British Museum. These remains consisted almost wholly of numerous broken jaws and teeth. The smallest of these animals were no bigger than mice, the largest scarcely as big as kittens. They had been monographed many years before by Sir Richard Owen and catalogued and revised by Lydekker. Moreover, Professor Marsh had recently published a paper describing corresponding forms from the dinosaur-bearing beds of Jurassic age in Wyoming. Nevertheless the young American, somewhat rashly perhaps, made his own independent studies on the originals and the results,[11] imperfect as they undoubtedly were, fully justified his efforts. For in the first place it was well that these oldest known relics of the mammalian class should be so carefully restudied by a young mind and from the evolutionary viewpoint; and although, as Osborn recognized, the fossil record was still too imperfect to give final answers, yet the fragments did establish the facts that at a period as far back as the lower Jurassic the multituberculate mammals were already an ancient and highly specialized side branch, while the remaining families were diversely specialized away from a still more ancient primitive insectivorous type; also that some of them seemed to be more nearly related to the stem of the marsupials, others to the earliest insectivores of the placental series.

Secondly, Osborn's work on the Mesozoic mammals appeared to him to have brought considerable support to Professor Cope's view of the way in which the "tritubercular" type of molar tooth seen in many of the Lower Eocene mammals had in its turn arisen from the single-tipped molars of the Upper Triassic *Dromatherium*.

After studying the teeth of these oldest known true mammals, the contemporaries of the older Jurassic dinosaurs, Osborn went on to develop and apply Cope's theory in a series of papers dealing with the "Evolution of Mammalian Molar Teeth to and from the Triangular Type," which were eventually (1907) brought

[11] "The Structure and Classification of the Mesozoic Mammalia." Journ. Acad. Nat. Sci. Philadelphia, vol. IX, no. 2. 1888.

together in the well known book of that title. Thus he became the founder with Cope of what is commonly called the "Cope-Osborn theory of Trituberculy," which has been of incalculable value to vertebrate palaeontologists, since it placed in their hands what Osborn called a key to the complexities of the highly diversified patterns of the molar teeth of mammals. Osborn's fruitful labors in this field must here be dismissed with the foregoing lines but they have been elsewhere summarized by the present writer.[12]

For many years prior to Osborn's work on Mesozoic mammals Cope and Marsh had been engaged in their strenuous rivalry and struggle for prior discovery and publication of the fossil vertebrates of the West. Osborn and Scott even in their first "Palaeontological Report of the Princeton Scientific Expedition" were almost inevitably ranged on the side of Cope, from whom they received much encouragement and practical assistance. For example, after describing the skull and dentition of their supposedly new genus and species, *"Leurocephalus cultridens,"* they write (p. 48): "This may eventually prove to be a species of *Telmatherium* (Marsh); but the description given by him is so brief and uncharacteristic that it might apply to any of the allied genera. Indeed, Dr. Leidy has regarded it as a synonym of *Palaeosyops*." Again, in his first independent memoir, that on *Loxolophodon* and *Uintatherium* (1881), Osborn implied that Marsh followed Leidy in the exploration of the Bridger beds, a statement which was flatly contradicted by Marsh in his memoir on the Dinocerata (1886, p. 236).

Whatever may have been the merits of the original controversy, it seems to have led, at least indirectly, to a serious clash between Osborn and Marsh over the Mesozoic mammals. Osborn in 1891 published a critique of Professor Marsh's "Discovery of the Cretaceous Mammalia," in which he tried to show that Marsh had applied a great many generic and specific names to the isolated parts of the highly differentiated dentition of a single type of multituberculate. Marsh replied ("Note on

[12] "A Half Century of Trituberculy: The Cope-Osborn Theory of Dental Evolution." Proc. Amer. Philos. Soc., Vol. LXXIII, No. 4, April, 1934, pp. 169-317 [Osborn's theory and diagrams, 181-186].

Mesozoic Mammalia") with a vitriolic review of Osborn's monograph on the Mesozoic Mammalia, to which Osborn in turn (1891) very soon came back with a vigorous rejoinder. A careful reading of the documents impresses the present writer that Osborn more than held his own in this affair and that he revealed himself as by no means unwilling to defend his right.

After Osborn's vitalizing contact with the English leaders in evolution it is not surprising that he retained an abiding interest in all the larger questions of evolution, such as the relations between natural selection and the Lamarckian factor of use and disuse. It was not until 1889, however, that he began a long series of communications in this field with his paper on "The Palaeontological Evidence for the Transmission of Acquired Characters." The series was continued at intervals to the close of his life. It is so intertwined with more limited subjects that one finds difficulty in separating the titles of his papers that deal with the factors of evolution from those treating of the historical evidences of the process. Thus he himself (1930, pp. 101-106) lists no less than eighty-five titles under the head of "Biology and New Principles of Evolution," after excluding all those that dealt with the evolution of man and with "Evolution and Religion in Education." However, many of the entries on his list are secondary sources, such as reviews or accounts of his addresses, interviews and popular articles in the daily press, and the like. Nevertheless, after all necessary deductions have been made, his publications on the general principles of evolution reach a formidable total. His main conclusions on the ways of evolution are summarized below (p. 82).

AT COLUMBIA UNIVERSITY

From 1873, when the young Osborn entered Princeton, to 1891, he was in residence there except for brief periods abroad. He was married [13] on September 29, 1881, to Miss Lucretia Thatcher Perry, daughter of General Alexander J. Perry, U. S. A., and was the father of five children. He had a delightful home in Princeton and every prospect of remaining

[13] "After Twenty Years . . . ," p. 74.

peacefully there as Professor of Comparative Anatomy and free to follow his own bent in palaeontology for the rest of his life. Then, when he was only thirty-four years of age, came the call to Columbia (1891) and the simultaneous call to the American Museum of Natural History. To Columbia,[14] at that time in the early stages of its transformation from a small college to a great university, he was called by President Seth Low in order to plan, establish and head the new department of biology. To the American Museum [15] he was called by President Morris K. Jesup to found and guide a department of mammalian palaeontology. Perhaps no one now living knows the exact steps by which these two calls were so completely synchronized and integrated but the twofold relationship proved to be most fortunate and far reaching.

At Columbia the legacy of Charles M. Da Costa made it possible to develop the new department of biology upon a liberal scale. The department was organized under Professor Osborn's direction in 1891,[16] but it was not opened until 1892. Professor Osborn was made Da Costa professor of zoology; Professor Edmund B. Wilson was called from Bryn Mawr for invertebrate zoology; Dr. Bashford Dean of Columbia University, who had been associated with Professor John Strong Newberry in the study of Palaeozoic fishes, was made instructor in vertebrate zoology. For the first six years the department was carried on in a laboratory at the College of Physicians and Surgeons.

Early in 1892 Professor Osborn delivered a series of three lectures on "Present Problems in Evolution and Heredity." These were addressed to the alumni of the College of Physicians and Surgeons. They constitute an admirable summary and analysis of current literature bearing on the following, among other topics: the meaning of "anomalies" and "reversions" in human anatomy, the relations of development, balance and

[14] "A History of Columbia University," 1754-1904. . . . New York, 1904, pp. 155-156.

[15] The American Museum of Natural History . . . : Annual Report of the Trustees. . . . Twenty-third Annual Report of the President, 1891. New York, 1892, p. 10.

[16] "Zoology at Columbia." Columbia University Bulletin, December, 1897.

degeneration, chiefly in human bones and muscles; history of the heredity theory, contrasting claims of Lamarckian and Weismannian schools; factors of evolution, difficulties in the natural-selection and use-and-disuse theories; nature of the relations between the body cells and the germ cells; phenomena of cell division, including distribution of the chromatin substance to the tissues; nature of fertilization, and the like. These topics were destined to be dealt with later in great detail by others in Professor Osborn's new department and it was characteristic of him that he undertook the great labor of preparing such a series and that he was measurably successful in correlating so many specialities in a broad, comprehensive, and at the same time well documented presentation.

The breadth of scope of Professor Osborn's lectures at Columbia, together with his excellent blackboard drawings, aroused the enthusiastic appreciation of both undergraduate and graduate students. He was soon elected the first Dean of the Faculty of Pure Science in Columbia University, which position he held for three years.[17] In the meantime he had supervised several scientific expeditions by members and graduate students of the department and had instituted the Columbia University Biological Series of books, outlining its scope and editing it for several years. Volume I of the series, his own "From the Greeks to Darwin: An Outline of the Development of the Evolutionary Idea," was based on a series of lectures which he had delivered on this subject. In it he traced the history of the idea of evolution from its more or less obscure adumbrations among the Greek philosophers and the fathers of the Church to the more immediate predecessors and contemporaries of Darwin. With regard to the place of Aristotle in the history of the discovery of evolution, Osborn concluded (p. 57) that "Aristotle had substantially the modern conception of the evolution of life from a primordial soft mass of living matter to the most perfect forms, and that even in these he believed evolution was incomplete for they were progressing to higher forms." This interpretation of Aristotle's views has, however, been

[17] "Fifty-two Years of Research . . . ," p. 153.

shown to be incorrect by Harry Beal Torrey and Frances Felin,[18] for although Aristotle recognized the existence of intermediates, for example, the ascidians, as supposedly partaking of the nature of both plants and animals, yet he was a firm believer in the Platonic doctrine of eternal "forms," including what are now called organic species. Osborn, in short, put together Aristotle's recognition of individual development and of gradational characters between otherwise distinct forms and then imputed to Aristotle a belief in phylogenetic progression.

While Columbia was preparing to remove to its new site at Morningside Heights, Professor Osborn and his colleagues in the department of biology spent a great deal of time and effort in planning the new laboratories, library and offices of the department, which were to be located in the Natural Science building presented by William C. Schermerhorn. All this was successfully done; Professor Osborn delivered an address, "The Corner Stones of Learning," on the occasion of the dedication of the new site at Morningside Heights on May 2, 1896, and supervised the installation of the department in its new home in 1897.[19]

Under his leadership a number of important contributions were made to various broad problems of evolution in which he was particularly interested. Dr. Oliver S. Strong published a detailed analysis of the brain and cranial nerves of the frog. Dr. Arthur Willey prepared a valuable work on "*Amphioxus* and the Ancestry of the Vertebrates." Dr. Bashford Dean produced his remarkable textbook on "Fishes, Living and Fossil" and his colleague Dr. Edmund B. Wilson published his great work on the Cell.

Osborn continued to give regular lectures in his Columbia courses on the Evolution of the Vertebrates and on the Evolution of the Mammals until about 1907, but gradually, owing to increasing pressure of other work, he handed over his courses to the present writer, who was for many years his assistant at both Columbia University and the American Museum. Mean-

[18] "Was Aristotle an Evolutionist?" Harry Beal Torrey and Frances Felin in Quarterly Review of Biology, Vol. 12, No. 1, March, 1937, pp. 1-18.

[19] "Zoology at Columbia," Columbia Bull., December, 1897.

time his graduate courses had been transferred to the department of vertebrate palaeontology at the Museum in furtherance of a plan adopted by both institutions for close coöperation in this matter. Osborn was made research professor of vertebrate palaeontology at Columbia but generously arranged for the reversion of his salary to the department of zoology there.

AT THE AMERICAN MUSEUM OF NATURAL HISTORY

A. As Curator

Returning to the other main stream of Professor Osborn's activities, we find him losing no time in organizing his department of mammalian palaeontology at the Museum, which opened in May, 1891, and in sending an expedition to the Lower Eocene beds of Wyoming. His first assistant was Dr. J. L. Wortman, one of Cope's former collectors, a man well trained in human anatomy, in field geology and in the technique of taking out fossils from their stony beds. Osborn's second assistant was Charles Earle, one of his graduate students at Princeton, who was then busy on a memoir on the genus *Palaeosyops* and its allies. Another assistant was Mr. O. A. Peterson, who eventually became curator of palaeontology in the Carnegie Museum of Pittsburgh.

The first expedition of the department was highly successful in the discovery of fossil remains; the report on these by Osborn and Wortman in 1892 deals with: the "homologies and nomenclature of the mammalian molar cusps (H. F. O.), the classification of the Perissodactyla (H. F. O.), the ancestry of the Felidae (J. L. W.), the taxonomy and morphology of the Primates, Creodonts and Ungulates (H. F. O.), geological and geographical sketch of the Big Horn Basin (J. L. W.), and Narrative of the Expedition of 1891 (J. L. W.)," each under the individual author's initials. Here we see Osborn, who had collaborated so harmoniously with Scott but had been forced by his removal from Princeton to dissolve that partnership, continuing this general policy of partnership, first with Wortman, then with Earle, later with Matthew and with many others, to

whom he never failed to give generous acknowledgment as well as access to priceless material.

To return to the first report on the collection of Lower Eocene mammals, the joy of discovery shines on almost every page and the cautious following of the elders which was evident in the early palaeontological papers has now given place to confidence based on previous triumphs. One is tempted to comment on many of the ideas in this and succeeding palaeontological reports in the American Museum Bulletins but there is space for only the following item. After describing the construction of the fore foot in the oldest known species of *Palaeosyops,* Osborn writes: "In short, this foot is distinctly mesaxonic and functionally tridactyl, whereas the later forms from the Bridger are, so far as known, paraxonic and functionally tetradactyl; in other words, we find an early species with a more progressive and modified form of foot than the later species, a state of affairs which is decidedly inconvenient for the evolutionist." It remained for Dr. W. D. Matthew, one of Osborn's graduate students at Columbia, later Assistant Curator and eventually Curator in the Museum, to bring forward the palaeontologic evidence that as regards the evolution of the fore foot in perissodactyls, Cope, followed by Osborn, was looking at evolution through reversed mental glasses; that is, they had mistaken what was really the older and more primitive condition for an advanced specialization. Osborn himself was well aware of the human proneness to error and never took it badly when his assistants, whom he had chosen because of their originality, differed from him.

In 1895 the title of the department of mammalian palaeontology was changed to department of vertebrate palaeontology, as better defining the more inclusive character of its collections.* This year was notable for the purchase of Professor Cope's great collection of fossil mammals of North America, including nearly 10,000 specimens representing 483 species from the chief horizons of North America. For the gift of this collection the Museum was indebted not only to President Jesup and other

* Annual Report of the President for 1895, American Museum of Natural History, New York, 1896, p. 16.

trustees but to Professor Osborn's father, William Henry Osborn, as well as to Professor Osborn himself. Meanwhile, year after year, Museum expeditions continued to discover new fossil mammals in the Rocky Mountains and Great Plains.

The subsequent history of the department of vertebrate palaeontology under Osborn's leadership would require a volume in itself and even if we limit our attention to the chief works in which Osborn himself took a particularly active part, the list would be too long for more than passing comment. However, one may mention the following:

(1) The discovery of numerous dinosaur remains in the course of many Museum expeditions in the Rocky Mountains and in Alberta, chiefly under Barnum Brown; described in the memoirs and bulletins, by Osborn and his assistants, on *Diplodocus, Brontosaurus, Morosaurus, Tyrannosaurus, Ornitholestes, Struthiomimus,* and others.

(2) The studies on the ordinal classification of the reptiles by Osborn and McGregor, which resulted in the proposed subdivision of the entire class into two subclasses, Diapsida and Synapsida. This classification became the stimulus for many others by subsequent authors.

(3) Osborn's studies on the origin of the mammals from the mammal-like reptiles and on the origin of birds from the Permian ancestors of the dinosaurs, although not based on specimens originally described by him, were marked by insight and good sense and have not yet been superseded except in details.

(4) His studies on the classification and phylogeny of the fossil rhinoceroses of Europe and North America, leading to: (a) his recognition of the differences in the length-breadth proportion of the skulls (in "dolichocephalic, mesaticephalic and brachycephalic" types), and of the feet (in "dolicho-mesati- and brachypodal" types); (b) his use of these characters as diagnostic of numerous subfamilies; (c) his conclusion that, contrary to his earlier beliefs, the rhinoceroses were exceedingly "polyphyletic" during the greater part of the Tertiary period.

(5) His studies on the classification and evolution of the titanotheres, culminating in the great two-volume monograph on this family, which was completed in 1920 and published by the

United States Geological Survey in 1929. Here the principles used in the rhinoceros studies were further developed and the taxonomic results were made the basis for many conclusions regarding the ways in which evolution has taken place. The history of the family was followed in great detail from the later part of the lower Eocene through the middle and upper Eocene to the top of the lower Oligocene. The fossils show that during this time the race increased in size from animals that were about as large as racehounds to huge beasts rivalling the modern elephant in bulk, though not in height. Although divided into many parallel and divergent lines, all became extinct, at least in North America, by the close of lower Oligocene times.

In seeking answers to the question, "What may have caused the sudden extinction of this race?" Osborn searched the vast literature of extinction in animals and compiled over one hundred causes and conditions that may have contributed to the extinction of different kinds of herbivorous mammals. The extinction of the titanotheres he attributed in part to the fact that in them the evolution of the cheek teeth was far more retarded than in other perissodactyls and he supposed that they were crowded out by more efficient competitors.

(6) Osborn's continuous studies on the correlation of fossil mammal-bearing horizons of Europe and North America, which were begun in his earliest memoir (on *Loxolophodon,* 1881), together with his many publications on the fossil mammals of the Tertiary, supplied the basis for his textbook, "The Age of Mammals in Europe, Asia and North America" (1910), which, although compiled with the aid of several assistants, constitutes one of his greatest and most useful works.

(7) For many years Osborn supervised the work of assistants in compiling a vast deposit of excerpts from the scientific literature of the species and breeds of horses, asses and zebras. It was his intention to work this up into a monograph on the Equidae, living and fossil, but other interests, particularly the Roosevelt Memorial and the Proboscidea Monograph, prevented him from realizing this ambition; consequently a great part of the material he amassed still lies untouched. However, his efforts in this direction led to three important results:

(a) Mr. William C. Whitney provided funds for exploration and research by the aid of which the Museum's collection of fossil Equidae received many important accessions; Mr. J. W. Gidley, under Osborn's direction, secured among other valuable material a beautiful skeleton of *Neohipparion whitneyi*.

(b) Mr. Samuel Harmsted Chubb was engaged in 1901, and even at this writing (1937) is still engaged in preparing a superb series of mounted skeletons representing the principal species and breeds of horses, asses and zebras and illustrating characteristic postures and movements of the animals in life; at the same time a great study collection of recent Equidae skeletons and dentitions has been built up.

(c) At Professor Osborn's request, Dr. W. D. Matthew prepared the first draft for a revision of the fossil Equidae of the Oligocene, Miocene and Pliocene of North America, accompanied by an extensive series of excellent illustrations. This was intended to have been a joint work by Osborn and Matthew but the latter adhered firmly to the so-called "horizontal" or zonal system of defining and classifying genera, whereas Osborn was an enthusiastic exponent of his own "phylogenetic" or vertical method of putting remote ancestor and descendants in the same "genus." This difference finally resulted in a deadlock, in which Matthew withdrew from the work and refused to collaborate with Osborn. At the same time, however, he handed over all his manuscript and had no objection to Osborn's using it as he saw fit, but he refused to allow his name to be used as co-author of the published work. In this awkward situation Osborn made the following frank and generous acknowledgment in the preface to the memoir.

"The author is chiefly indebted to the original researches by Matthew mentioned above (Matthew, 1913) on the Miocene and Pliocene species of Equidae in the collections of the American Museum of Natural History. At first a joint report was contemplated; but for certain reasons it has appeared wiser that the present revision should appear under a single name. The author issues it, therefore, with the fullest acknowledgment of his indebtedness to his colleague, from whose descriptions, observations, and definitions many quotations are taken entire

without amendment. On certain points of difference of interpretation and opinion which have arisen the author holds himself wholly responsible."

In spite of these regrettable but sincere differences the memoir contains superb material for the study of evolution.

(8) Osborn's studies for "The Age of Mammals" naturally led him to plan a corresponding volume on the Age of Man. In 1912 a rapid motor tour through those parts of Europe that contain the principal sites of the Palaeolithic cultures gave him a general introduction to the subject and three years later appeared his "Men of the Old Stone Age, Their Environment, Life and Art." He was assisted in this work by Miss Christina D. Matthew. The text was illustrated from photographs of the carefully studied reconstructions by Professor J. H. McGregor of the skulls and external features of the head of *Pithecanthropus* and of the Neanderthal and Cro-Magnon men. Further studies, on the correlation of the divisions of the Pleistocene of Europe and North America, were made with the collaboration of Dr. Chester A. Reeds.

"Man Rises to Parnassus" is chiefly based on the studies of Montelius and others on the Neolithic, bronze and iron cultures of Northern Europe, which Osborn also visited.

(9) Osborn's growing conviction of the great antiquity of many "phyla" of mammals gradually led him to the view that the human race had an equally long independent ancestry stretching back perhaps into Eocene times before merging in a common stock with the remote ancestors of the anthropoid apes. Partly for this reason he refused to assent to the theory that man's ancestor had ever been an ape. Vigorously attacking the "ape-man theory" as a "myth," he wrote enthusiastically that humanity should be grateful to the anthropologist for having freed man from the bar sinister of ape ancestry. Against these and similar utterances the present writer felt compelled to enter a vigorous demurrer and on several occasions Osborn and the writer presented these opposing views from the same platform. It was greatly to Osborn's credit that he refrained from using his power to silence his former assistant and that he always treated the latter not only with perfect fairness but with unfail-

ing friendship, so that to the day of his death there was never a cloud between them.

(10) Osborn's last and in many respects his greatest work was the monograph on the Proboscidea, projected in 1908 but not fairly begun as a monograph until 1920. The first volume, including 802 pages and 680 figures and 12 plates, was published on August 15, 1936, nine months after his death; the second volume, which will appear in 1939, will be of about the same size. The main results are that the order Proboscidea is divided into five superfamilies, eight families, twenty-one subfamilies, forty-four genera and about three hundred and fifty species, including subspecies and varieties, mostly on differences in the molar teeth, incisor tusks, jaws and form of skull. This was perhaps the climax of "polyphyletism."

(11) By no means the least of Osborn's gifts to the Museum was the Osborn Library of Vertebrate Palaeontology, including at the time of his death about 8,000 bound volumes, several thousands of "separata," together with a subject index of possibly 70,000 entries.

B. As President

The annual reports of the President of the Board of Trustees of the American Museum of Natural History from 1908 until 1933 contain a great deal of material relative both to the growth of the Museum and to the ideals which guided that growth during the presidency of Henry Fairfield Osborn. One reads there how, one after another, the new wings that had been planned during Mr. Morris K. Jesup's presidency (namely, all those on West 77th Street and the southwest wing on Columbus Avenue) were completed, and how the exhibition halls therein were opened one by one. And one also reads of the buildings planned under Professor Osborn's presidency, including the buildings along Central Park West, together with the African Wing, the Education Building, the Preparation and Power Building, the Roosevelt Memorial, built by the State of New York; one after another these were completed and connected with the general system. And in a special publication on the plan and scope of the Museum are set forth Osborn's plans for the future development and completion of the entire Museum. But in these publi-

cations the reader receives hardly a hint of the *vis-a-tergo* that was constantly being exerted by President Osborn upon the Museum Trustees and the city and state officials by whom the necessary enactments and appropriations were in every case to be approved and put into effect.

Nor does the reader easily derive from these somewhat formal reports such a vital portrait of Henry Fairfield Osborn, President of the Museum, as was presented the day after his death by Dr. George H. Sherwood, Director of the Museum during the greater part of Professor Osborn's presidency.

"Professor Osborn has left behind him a splendid record of service to the American Museum, covering a period of more than forty years. He was our president for a full quarter of a century, an epoch in the Museum's history which witnessed unprecedented development in all its branches—physical, financial, scientific, and educational. Under his leadership and direction the building space was more than doubled; the city's annual appropriation for maintenance increased from approximately $160,000 to the half million mark; the endowment, the backbone of the Museum's life, multiplied from $2,000,000 to more than $14,000,000; the Museum membership increased over 400 per cent; the scientific staff was more than trebled; the earth was dotted with our expeditions; collections of priceless value were brought within our walls; volumes of publications, scientific and popular, were issued and given world-wide distribution; the artistic standard and effectiveness of Museum exhibitions was vastly improved; while the popular presentation of natural history and kindred subjects was made so appealing that many technical scientific terms became household words.

"Throughout President Osborn's administration it was my privilege and good fortune to stand at his elbow. In this long association, therefore, I had exceptional opportunity to observe, feel, and *know* his character and personality. Words of mine would be wholly inadequate to summarize his achievements or evaluate his contributions to human knowledge. Therefore I wish to speak merely of a few of his characteristics which were outstanding and have left on us a vivid impression of a great man.

"Notable was his *breadth of vision*. While his special science was palaeontology, it was the Museum as a whole that was of paramount importance, and every department had his genuine interest. Always was he keen for developments which would make our institution a greater power in science and education. For example, I well remember his enthusiasm when he first learned of the wonderful instrument called the Zeiss Planetarium. It was only a few weeks later that he dispatched Doctor Fisher to Germany to bring back first-hand information of it.

"Next I have in mind his *tenacity of purpose*. Here was a man born to wealth who might have led a life of luxury and ease. Instead, he set out with the determination to make his mark in the field of science—and he did. This same tenacity of purpose he applied to the administration of the Museum. Obstacles did not deter him. They were there to be overcome and he forged ahead. When he was sure he was right, no one, not even his most intimate friends, could swerve him from what he felt was his path of duty.

"Third I place his *fertility of mind*—and what fertility it was! He could think of enough things that ought and must be done to keep a regiment of us busy. Oftentimes I wished his mind weren't quite so fertile and that we might have time to catch up with his ideas or complete some of the problems on hand. Still it was this fertility of mind that kept us on our toes and urged us on to achievement.

"Another outstanding characteristic was his *sympathy with youth*. He had an affectionate regard for all children and nothing gave him so much pleasure as to see the classes of school children streaming into the Museum. . . .

"Finally I mention the Professor's *eternal optimism*. He had a philosophy of life which carried him over discouragements that would have floored a less virile nature. Again and again I have seen him up against difficulties that were simply overwhelming, and invariably he would come up with a smile on his face. And so I feel that if he were here today he would not want us to consider this a time for sorrow or sadness at the loss of a dear friend, but rather would wish us to reflect on the

achievements of his administration and do our best to carry on his ideals."

Osborn's presidency was important to the Museum also because he constantly insisted on very high standards of beauty in the mounted groups, in mural paintings and other decorative features of the exhibition halls.

HIS LEADERSHIP IN OTHER SCIENTIFIC AND EDUCATIONAL ORGANIZATIONS

Professor Osborn's brilliant successes at Columbia University and the American Museum encouraged other scientific and educational organizations to look to him for leadership. The American Society of Naturalists started the ball rolling in 1891 by electing him as its President.[20] The next year the American Association for the Advancement of Science made him one of its Vice Presidents. The New York Academy of Sciences, the New York Zoological Society, the Marine Biological Association of American Colleges, the American Morphological Society and later organizations, elected him at different times to their presidencies. And a greater presidency overtook him in 1908 when he succeeded Mr. Morris K. Jesup as the head of the American Museum.

Soon after coming to New York he began to take an active part in the meetings of the New York Academy of Sciences, presenting there many of his palaeontological results and serving in 1894-96 as Vice President and in 1898-1900 as President of the Academy. He was especially influential in bringing about the permanent affiliation of the Academy with the Museum and the eventual transfer of the Academy itself to the Museum buildings. His two annual addresses as President of the Academy in 1899 and 1900 dealt extensively with "Correlation between Tertiary Mammal Horizons of Europe and America." In the first address he analyzed the evidences of parallelism between the successive horizons of Tertiary mammals on opposite sides of the Atlantic. In the second address he dealt espe-

[20] "After Twenty Years . . . ," p. 73.

cially with the faunal succession and geographical distribution of the orders and families of mammals on the different continents. This led to his "theory of successive invasions of an African fauna into Europe"; this was that the Ethiopian region [in the broad sense] or South Africa was a great center of independent evolution for the "Proboscidea, Hyracoidea, certain Edentata, the antelopes, the giraffes, the hippopotami, the most specialized ruminants, and among the rodents, the anomalures, dormice and jerboas, among monkeys, the baboons. . . ." These, he suggested, "may all have enjoyed their original adaptive radiation in Africa. . . ."

"On the other hand," he concludes, "certain families had an exclusively Eurasiatic history, so far as we know." These are, among others, "the anthropoid apes. . . ." Again in another passage: "Northern Asia is unknown palaeontologically until the Pleistocene—here is a region for explorers. However, we may consider it as part of a broad Eurasiatic land area—extending from the Rocky Mountain region to Great Britain. The faunal relations are astonishingly close, between the new and old worlds at this time. Every year's discovery increases the resemblance and diminishes the differences between Europe and the Rocky Mountain region."

The next year (1901) Charles W. Andrews of the British Museum began to announce the palaeontological discoveries that were being made in the Fayûm district in Egypt, which proved that at least two early stages in the evolution of the Proboscidea had indeed lived in Africa. The verification of the "prophecy" that northern Asia would be proved to have been part of a broad Eurasiatic land mass, containing important evidence of the faunal interchange between Asia and North America, had to wait until 1922-30, when Roy C. Andrews, another of Professor Osborn's assistants, opened up the great "Lost World" of the Gobi desert.

Professor Osborn was one of the charter members of the New York Zoological Society (1895). In 1896 he presented a joint report, with C. Grant La Farge and Andrew H. Green, embodying a "Preliminary Plan for the Prosecution of the

Work of the Zoological Society." He was chairman of the executive committee from 1896-1903, 1907-1909, President from 1909-1924 and Honorary President from 1927 until his death.

He had a great deal to do with the selection of the site of the Society's Park and with the planning and general style of its buildings and grounds. He was particularly interested in the development of the collection of living proboscideans, perissodactyls and other ungulates. With Mrs. Osborn's unfailing assistance, he was successful in enhancing the social prestige of membership in the Society and attracted many of the leading families of New York to its support.

He gave powerful aid to the Director, Dr. W. T. Hornaday, in the latter's sustained agitation for the protection of native wild life. As Honorary President of the American Bison Society, he assisted Dr. Hornaday in rescuing that species from the extinction with which it was threatened. Ably seconding his friends Madison Grant and John C. Merriam, he was one of the founders of the "Save the Redwoods League," which was finally successful in having certain sequoia-bearing areas set aside as permanent sanctuaries for those noble monuments of long past ages.

Always impartially supporting the researches and expeditions of all members of the staff, he was nevertheless particularly interested in the numerous expeditions and researches of Dr. William Beebe, in the publication of the latter's great monograph on the Pheasants, in the establishment of the Department of Tropical Research, and in the *Arcturus* expedition to the Sargasso Sea and the Galapagos Islands.

To Professor Osborn the animals of the Zoological Society's Park were by no means to be regarded as captives, brought together merely for the amusement of the public. They were, on the contrary, the ambassadors and representatives of the noble races that ruled the world during the Age of Mammals.

Osborn was also active in the American Philosophical Society and the National Academy of Sciences, attending many of the regular meetings and serving on various committees.

SUMMARY OF OSBORN'S VIEWS ON EVOLUTION

The present writer has elsewhere [21] summarized Osborn's chief ideas on the theory of evolution as follows:

(1) The law of *continental and local adaptive radiation;*

(2) The law of *homoplasy* or parallel but independent evolution in related lines of descent;

(3) The law of *tetraplasy,* whereby evolution results not from the operation of single causes, but as the resultant of forces from four principal directions (external environment, internal environment, heredity, selection).

(4) The law of *alloiometry,* or adaptive modification of dimensions of the skull, feet or other parts, arising independently in different lines of descent.

(5) The law of *rectigradation,* or *aristogenesis;* i. e., the gradual appearance during long ages of new structural units of adaptive value, predetermined in the germ plasm and in their initial stages independent of natural selection;

(6) The law of *polyphyly;* i. e., the normal occurrence of many related lines of descent, derived eventually from a common stock, but coexisting throughout great periods of time.

Osborn himself was under no delusion as to the lack of enthusiasm with which his writings on the theory of evolution were received in many quarters. In his autobiography he writes (p. 73):

". . . . it is important to warn the investigator that the assemblage of new facts and observations and what may be called the first line of conclusions or generalizations drawn from these observations makes much more rapid headway in science than the contemporary or final assemblage of new principles. In my own experience, the *facts and observations* I have assembled, with the aid of my colleagues, have gained world-wide acceptance and the subject of vertebrate palaeontology, with the contemporary work of other investigators along the same lines as my own, has become a matter of widespread knowledge and interest, whereas a half-century ago it reached only the scientific and cultured classes. . . .

[21] Science, Nov. 15, 1935, Vol. 82, No. 2133, pp. 452-454.

"The inductive line of investigation for the *new biologic principles* gained by extensive-intensive research advances much more slowly because it has to meet and contend with other principles strongly entrenched in the minds of observers in different fields of biologic research. . . .

"The new principles which I have enunciated from fifty-two years of palaeontological research—of Continuity, of Adaptive Rectigradation, of Allometrons—as well as the theory of Tetraplasy and Tetrakinesis, *have, so far as I know, gained no acceptance in the current realm of either biologic or palaeontologic thought.* The environmental principle of Adaptive Radiation, of polyphylogenetic evolution and of harmonic classification has, on the other hand, gained wide acceptance among palaeontologists and some measure of acceptance among zoologists.

"One need not be impatient; *if new principles are sound they will finally gain universal acceptance; if unsound, the less widely they are accepted the better.*"

RETROSPECT

In the midst of his diverse administrative labors Osborn found time to produce an enormous amount of manuscript for the printers, ranging over a wide variety of subjects. With the assistance of Miss Jannette M. Lucas and Miss Ruth Tyler, a critical examination of the nine hundred and forty-four entries in his complete bibliography was undertaken, with a view of measuring the size of his output in the six successive decades of his productive career. After careful consideration, corrections were made for the work of collaborators and assistants, for bibliographies and other clerical matter. Even with all these deductions he was the author of some 11,464 printed pages, not counting the still unpublished Volume II of the Proboscidea monograph, which would bring the total up to well over 12,000.

The net total outputs for the successive periods were as follows:

Periods	1878-88	1889-98	1899-08	1909-18	1919-28	1929-38
Net total pages.....	397	1,391	1,188	2,695	3,232	3,197 est.

Grand total 12,100.

These figures should, of course, be used with caution, since they show primarily not when the material listed was produced but when it was published. For example, by far the greater part of the copy for the great two-volume memoir on the Proboscidea was prepared by him before 1931, but owing to inevitable delays the work was not published until several years after his death. Moreover, a page containing an analysis of the phyla of the Mastodontidae cost the author far more time and effort than did a dictated page of the president's annual report.

Turning to the relative abundance of different subjects in successive periods, we have the following comparison expressed in net number of pages published, omitting miscellaneous matter, newspaper reports and the like.

	1878-88	1889-98	1899-08	1909-18	1919-28	1929-38	Net Totals
Palaeontology	237	709	920	1,205	547	2,552	6,170
Psychology	34	0	0	0	0	0	34
Neurology	77	2	0	0	0	0	79
Embryology	45	0	4	0	0	0	49
Heredity	1	104	0	0	29	9	143
Biography	3	76	20	219	771	143	1,232
Education	0	85	64	68	422	17	656
Administration	0	51	59	445	451	335	1,341
Evolution (Theory)	0	338	90	155	105	108	796
Anthropology	0	26	5	580	492	31	1,134
Conservation	0	0	26	23	44	0	93
Science and Religion	0	0	0	0	371	2	373
	397	1,391	1,188	2,695	3,232	3,197	12,100

From the figures above it will be seen that Osborn's strictly palaeontological writings constituted more than fifty per cent of his entire output. His contributions to psychology, neurology and embryology were relatively brief and practically limited to the first decade.

His publications under administration do not by any means measure his productive labors in that field, in which an enormous correspondence is on file and in which much was accomplished by personal contacts.

His publications listed under biography number about one hundred and six and range from brief single-page obituary notices to extensive works on Leidy, Cope, and Wallace. Especially in the longer biographies he endeavored to follow the historical development of the main ideas and principles that had been put forth by great men, who for the most part had been his own friends.

The Roosevelt Memorial, a building erected by the State of New York in memory of his lifelong friend, Theodore Roosevelt, may fairly be counted as Osborn's supreme achievement in biography, for although the first suggestion came from others, it was he, first as Chairman of the Roosevelt Memorial Commission, then as Chairman of the Board of Trustees of the New York State Roosevelt Memorial, who guided and inspired the entire project until it stood practically completed in the year of his death (1935). It is indeed a magnificent memorial in stone, bronze and mural painting, setting forth the life of a great naturalist, statesman and patriot.

The Roosevelt Memorial together with the American Museum of Natural History, with which it is articulated and integrated, affords a capital example of "creative evolution," the favorite principle of Osborn's later decades. As he watched wing after wing of the Museum itself and finally the capstone of the entire structure, the Roosevelt Memorial, rising under his wand, it is perhaps not surprising that he stressed the fact that there was something utterly new in the completed organization that was not present in any of its parts. He had repeatedly banished Chance from his cosmos and he therefore could not have granted that unpredictable combinations of diverse causal series had played a constant part in the development either of the Museum, or of the Roosevelt Memorial, or in his own history, or in the evolution of every organism of present and past ages.

"This discovery," he writes,[22] "of the firm and undeviating order with which palaeontology replaces all the chance explana-

[22] Address Delivered on the Occasion of the Dedication of the New Museum Building, 29 December, 1925: The Origin of Species, 1859-1925. Peabody Museum of Natural History, Bull. 1, no. 1, pp. 25-38.

tions of adaptation from Empedocles to Darwin is the supreme service which palaeontologic research renders to biology." But he does not tell us how, if there be no real freedom in the universe, the "creative evolution" of new effects becomes possible. In this connection, his brother, William Church Osborn, in response to an inquiry from the Reverend Henry S. Coffin, regarding the "long background which explains a man's view," attributed Henry Fairfield Osborn's view on creative evolution to the deeply religious nature of his mother and the training which she gave him in his formative years.

"He did not have a metaphysical mind," wrote his brother (*in litteris,* Dec. 3, 1935), "or a natural spirit of destructive skepticism. The whole tenor of his nature was towards creation and one of his last views on evolution was, if I correctly understood it, a belief that life contains within itself a creative power which leads it to adapt itself to its external surroundings and to create such new forms for itself as are required for its existence. This seems to me to be a distinctly religious conception as opposed to the mechanistic theory of straight survivalism by the selection of the fittest under the long processes of trial and error. I know that I once quoted to him a line from Lowell's 'Sir Launfal' which seemed to impress him deeply. I believe it is as follows:

> " 'Every clod feels a stir of might,
> An instinct within it which reaches and towers
> And, groping blindly above it for light,
> Climbs to a soul in grass and flowers.'

"I do not think he ever allowed what he did know to overcome his feeling for the vast reaches that he did not know but I think he carried his faith in the creative power over into the latter and regarded the subjects in which his life was spent as merely steps or processes in a great forwarding of creation."

Those of his scientific colleagues who were perhaps somewhat irritated by his numerous press interviews and publications dealing with religion and science failed to realize that he, as the

disciple of Dr. McCosh, consistently regarded evolution as an expression of the "firm and undeviating order" conceived by the divine creative mind.

That he was a deist, at least according to his own understanding of the term, there is no doubt. On the other hand, there is abundant evidence that he was not a Fundamentalist. He professed to be a Christian and although he was silent on doctrinal points, he lived in reverence to his God and in service to man.

It is not, however, as a harmonizer of religion and science that Osborn was acclaimed by his contemporaries and will be especially remembered by his successors. It is not even as the author of controversial writings in anthropology or of innumerable reviews and addresses on the theory of evolution. Republics are traditionally ungrateful and in the great universities that he served so well, his name, although engraved on the roster of their immortals, will become dim with time. Even the American Museum of Natural History may eventually forget that long ago he was its master builder. But to the future students of vertebrate palaeontology (and there will be many such if civilization endures) his numerous memoirs on fossil mammals will be an imperishable source.

And not the least of the great endowments that the world owes to Henry Fairfield Osborn is that, with the loyal aid of his colleagues and assistants, he founded and established a single great school of vertebrate palaeontology located in three harmoniously coöperating centers, Princeton University, Columbia University and the American Museum of Natural History; that in place of discord he left peace among the palaeontologists of America, many of whom are proud to have been either his students or students of his students.

A man of the highest ideals and standards as teacher, investigator, citizen; great in leadership and administration, a man of scrupulous honor, of disarming sincerity and fairness, generously giving credit to all who aided him, respecting the principle of academic freedom in his assistants even when they differed sharply from him. He was gentle, good humored, and consistently adored by his parents, brothers, wife, children and

grandchildren. His friends delighted in his society and his colleagues testified their admiration by awarding him the highest medals and honors in the leading scientific organizations of the world. And at the end of this crowded, happy life he died seated at his desk at Castle Rock, as he was preparing for another day's work on the Roosevelt Memorial.

BIBLIOGRAPHY OF HENRY FAIRFIELD OSBORN

(Extracted from the full bibliography in "Fifty-two Years of Research, Observation and Publication, 1877-1929," omitting references to newspapers, abstracts, preliminary announcements and popular articles.)

1878

Palæontological Report of the Princeton Scientific Expedition of 1877. (With W. B. Scott and Francis Speir, Jr.) *Contr. E. M. Mus. Geol. and Archæol. Princeton Coll.*, No. 1, pp. 7-106, pls. A and i-x.

1879

The Lower jaw of Loxolophodon. (With Francis Speir, Jr.) *Amer. Journ. Sci.*, (3), Vol. xvii, pp. 304-309.

On Some Points in the Early Development of the Common Newt. (With W. B. Scott.) *Quart. Journ. Micros. Sci.*, N. S., Vol. xix, pp. 449-475, pls. xx-xxi.

1880

Questions upon the Visualizing and other Allied Faculties. (With Francis Galton, F.R.S.) Privately printed, New York, 2-page leaflet.

1881

A Memoir upon Loxolophodon and Uintatherium, Two Genera of the Sub-Order Dinocerata. Accompanied by a Stratigraphical Report of the Bridger Beds in the Washakie Basin by John Bach McMaster. *Contr. E. M. Mus. Geol. and Archaeol. Coll. of New Jersey*, Vol. i, No. 1, pp. 5-54, pls. i-iv, 2 maps.

1882

Orthocynodon, an Animal related to the Rhinoceros, from the Bridger Eocene. (With W. B. Scott.) *Amer. Journ. Sci.*, (3) Vol. xxiv, pp. 223-225.

1883

On the Skull of the Eocene Rhinoceros, Orthocynodon, and the Relation of this Genus to Other Members of the Group. (With W. B. Scott.) *Contr. E. M. Mus. Geol. and Archæol. Princeton Coll.* Bull. No. 3, pp. 1-22.

On Achænodon, an Eocene Bunodont. *Contr. E. M. Mus. Geol. and Archæol. Princeton Coll.* Bull. No. 3, pp. 23-35.

Preliminary Observations upon the Brain of Amphiuma. *Proc. Acad. Nat. Sci. Phila.*, Vol. xxxv, pp. 177-186.

Observations upon the Fœtal Membranes of the Opossum and other Marsupials. *Quart. Journ. Micros. Sci.*, N. S., Vol. xxiii, pp. 473-484.

1884

A Study of the Mind's Chamber of Imagery. (With James McCosh.) *Princeton Review*, Vol. xiii, pp. 50-72.

Illusions of Memory. *North Amer. Review,* Vol. cxxxviii, pp. 476-486.

Visual Memory. *Journ. Christian Phil.,* Vol. iii, pp. 439-450.

Preliminary Observations upon the Brain of Menopoma. *Proc. Acad. Nat. Sci. Phila.,* Vol. xxxvi, pp. 262-274.

1885

A Simple Method of Injecting the Arteries and Veins in Small Animals. *Amer. Naturalist,* Vol. xix, pp. 920-921.

The Development of the Brain. *Reference Handbook, Medical Sci.,* Vol. i, First Edition, pp. 633-642.

1886

Observations upon the Presence of the Corpus Callosum in the Brain of Amphibians and Reptiles. *Zool. Anz.,* Band ix, pp. 200-205.

The Origin of the Corpus Callosum. A Contribution upon the Cerebral Commissures of the Vertebrata. *Morph. Jahrb.,* Band xii, pp. 223-251; pp. 530-543, pls. xiii, xiv, xxv.

Note upon the Cerebral Commissures in the lower Vertebrata and a probable Fornix Rudiment in the Brain of Tropidonotus. *Zool. Anz.,* Band ix, pp. 577-578.

Observations upon the Upper Triassic Mammals, Dromatherium and Microconodon. *Proc. Acad. Nat. Sci. Phila.,* Vol. xxxviii, pp. 359-363.

1887

Preliminary Account of the Fossil Mammals from the White River Formation contained in the Museum of Comparative Zoölogy. (With W. B. Scott.) *Bull. Mus. Comp. Zool.,* Vol. xiii, pp. 151-171, pls. i-ii.

The Relation of the Dorsal Commissures of the Brain to the Formation of the Encephalic Vesicles. *Amer. Naturalist,* Vol. xxi, pp. 940-941.

The Origin of the Tritubercular Type of Mammalian Dentition. *Science,* Vol. x, No. 254, Dec. 16, 1887, p. 300.

The Fœtal Membranes of the Marsupials. *Journ. Morph.,* Vol. i, pp. 373-382, pl. xvii.

The Triassic Mammals, Dromatherium and Microconodon. *Proc. Amer. Phil. Soc.,* Vol. xxiv, pp. 109-111, 1 pl.

Preliminary Report on the Vertebrate Fossils of the Uinta Formation collected by the Princeton Expedition of 1886. (With W. B. Scott.) *Proc. Amer. Phil. Soc.,* Vol. xxiv, pp. 255-264.

1888

The Mylohyoid Groove in the Mesozoic and Recent Mammalia. *Amer. Naturalist,* Vol. xxii, pp. 75-76.

Report of the Committee on Anatomical Nomenclature, with Special Reference to the Brain. (With Frank Baker.) *Proc. Amer. Assoc. Adv. Sci.,* Vol. xxxvi, p. 56.

A Review of Mr. Lydekker's Arrangement of the Mesozoic Mammalia. *Amer. Naturalist,* Vol. xxii, pp. 232-236.

A Contribution to the Internal Structure of the Amphibian Brain. *Journ. Morph.*, Vol. ii, pp. 51-96, pls. iv-vi.

On the Structure and Classification of the Mesozoic Mammalia. *Journ. Acad. Nat. Sci. Phila.*, (2), Vol. ix, pp. 186-265, pls. viii, ix.

The Nomenclature of the Mammalian Molar Cusps. *Amer. Naturalist*, Vol. xxii, pp. 926, 927.

Additional Observations upon the Structure and Classification of the Mesozoic Mammalia. *Proc. Acad. Nat. Sci. Phila.*, Vol. xl, pp. 292-301, pls. xxv, xxvi.

The Evolution of Mammalian Molars to and from the Tritubercular Type. *Amer. Naturalist*, Vol. xxii, pp. 1067-1079.

1889

The Palæontological Evidence for the Transmission of Acquired Characters. *Amer. Naturalist*, Vol. xxiii, pp. 561-566.

1890

Evolution and Heredity. Biol. Lectures, Marine Biol. Lab., Woods Hole, pp. 130-141.

Preliminary Account of the Fossil Mammals from the White River and Loup Fork Formations, contained in the Museum of Comparative Zoölogy, Part II—Perissodactyla. *Bull. Mus. Comp. Zool.*, Vol. xx, pp. 65-100, pls. i-iii.

The Mammalia of the Uinta Formation. III. The Perissodactyla. IV. The Evolution of the Ungulate Foot. *Trans. Amer. Phil. Soc.*, N. S., Vol. xvi, Pt. iii, pp. 461-572, pls. vii-x.

A Review of the Cernaysian Mammalia. *Proc. Acad. Nat. Sci. Phila.*, Vol. xlii, pp. 51-62.

1891

Are Acquired Variations Inherited? *Amer. Naturalist*, Vol. xxv, pp. 191-216.

A Review of the Cretaceous Mammalia. [Review of Marsh's "Discovery of the Cretaceous Mammalia" Pts. I and II.] *Proc. Acad. Nat. Sci. Phila.*, Vol. xliii, pp. 124-135. *Amer. Naturalist*, Vol. xxv, pp. 595-611.

A Reply to Professor Marsh's "Note on Mesozoic Mammalia." *Amer. Naturalist*, Vol. xxv, pp. 775-783.

Meniscotheriidæ and Chalicotherioidea. *Amer. Naturalist*, Vol. xxv, pp. 911-912.

1892

The Cartwright Lectures for 1892 before the Alumni of the College of Physicians and Surgeons, New York.—Present Problems in Evolution and Heredity. 1. The Contemporary Evolution of Man. 2. Difficulties in the Heredity Theory. 3. Heredity and the Germ Cells. *Medical Record*, Vol. 41, pp. 197-204; 253-261; 449-456; 533-534.

Nomenclature of Mammalian Molar Cusps. *Amer. Naturalist,* Vol. xxvi, pp. 436-437.

Palæonictis in the American Lower Eocene. *Nature,* Vol. 46, No. 1176, May 12, 1892, p. 30.

The Ancestry of Chalicotherium. *Science,* Vol. xix, No. 484, May 13, 1892, p. 276.

Is Meniscotherium a Member of the Chalicotherioidea? *Amer. Naturalist,* Vol. xxvi, pp. 507-509.

[Review.] Odontogenesis in the Ungulates. *Amer. Naturalist,* Vol. xxvi, pp. 621-623.

[Abstr.] A Reply to Professor Marsh's "Note on Mesozoic Mammalia." *Prac. Amer. Assoc. Adv. Sci.,* Vol. xl, p. 290.

What is Lophiodon? *Amer. Naturalist,* Vol. xxvi, pp. 763-765.

Fossil Mammals of the Wasatch and Wind River Beds. Collection of 1891. (With J. L. Wortman.) *Bull. Amer. Mus. Nat. Hist.,* Vol. iv, Art. xi, pp. 81-147.

The History and Homologies of the Human Molar Cusps. *Anat. Anz.,* vii Jahrg., Nos. 23, 24, pp. 740-747.

Characters of Protoceras (Marsh), the New Artiodactyl from the Lower Miocene. (With J. L. Wortman.) *Bull. Amer. Mus. Nat. Hist.,* Vol. iv, Art. xviii, pp. 351-371.

Biology and Other Science in the Schools. *Rept. Schoolmasters Assoc. New York and Vicinity,* 1892-3, pp. 35-42.

Sur la Découverte du Palæonictis en Amérique. *Bul. Soc. Géal. France,* (3), t. xx, pp. 434-436.

1893

Artionyx, a New Genus of Ancylopoda. (With J. L. Wortman.) *Bull. Amer. Mus. Nat. Hist.,* Vol. v, Art. i, pp. 1-18.

The Ancylopoda, Chalicotherium and Artionyx. *Amer. Naturalist,* Vol. xxvii, pp. 118-133.

Protoceras, the New Artiodactyl. *Nature,* Vol. 47, No. 1214, Feb. 2, 1893, pp. 321-322.

Artionyx—A Clawed Artiodactyl. *Nature,* Vol. 47, No. 1226, Apr. 27, 1893, pp. 610-611.

Aceratherium tridactylum from the Lower Miocene of Dakota. *Bull. Amer. Mus. Nat. Hist.,* Vol. v, Art. vii, pp. 85-86.

The Collection of Fossil Mammals in the American Museum of Natural History, New York. *Science,* Vol. xxi, No. 536, May 12, 1893, p. 261.

Recent Researches upon the Succession of Teeth in Mammals. *Amer. Naturalist,* Vol. xxvii, pp. 493-508.

Heredity in the Ovum and Spermatozoön. *Reference Handbook, Medical Sci.,* Supplement to Vol. ix, pp. 396-408.

Rise of the Mammalia in North America. *Amer. Journ. Sci.,* (3), Vol. xlvi, pp. 379-392; 448-466, pls. v-x.

School of Pure Science. Report of the Dean for the Academic Year ending June 30, 1893. *Fourth Annual Report of President Low to the Trustees*, pp. 141-149.

Fossil Mammals of the Upper Cretaceous Beds. *Bull. Amer. Mus. Nat. Hist.*, Vol. v, Art. xvii, pp. 311-330, pls. vii-viii.

Alte und neue Probleme der Phylogenese. *Ergebnisse, Anat. und Entwickelungsgesch.* Band iii, pp. 584-619.

A Three Year Course for the Degree (Ph.D.). *Columbia Univ. Miscel. Pub.*, 1893.

1894

The Degree of Doctor of Philosophy. Suggestions. (With Wm. A. Keener.) Reported in Minutes of Columbia Univ. Council dated January 16, 1894. 6 pp. Privately printed.

A Division of the Eutherian Mammals into the Mesoplacentalia and Cenoplacentalia. *Trans. N. Y. Acad. Sci.*, Vol. xiii, pp. 234-237.

Fossil Mammals of the Lower Miocene White River Beds. Collection of 1892. (With J. L. Wortman.) *Bull. Amer. Mus. Nat. Hist.*, Vol. vi, Art. vii, pp. 199-228, pls. ii-iii.

From the Greeks to Darwin. 8vo, Macmillan & Co., New York, 259 pp.

Certain Principles of Progressively Adaptive Variation Observed in Fossil Series. *Nature*, Vol. 50, No. 1296, Aug. 30, 1894, p. 435.

School of Pure Science. Report of the Dean for the Academic Year ending June 30, 1894. *Fifth Annual Report of President Low to the Trustees*, pp. 125-150.

[Preface to "Amphioxus and the Ancestry of the Vertebrates" by Arthur Willey.] Macmillan & Co., New York, 1894, pp. vii-ix.

1895

Environment in its Influence upon the Successive Stages of Development and as a Cause of Variation. *Science*, N. S., Vol. i, No. 2, Jan. 11, 1895, pp. 35-36.

Fossil Mammals of the Puerco Beds. Collection of 1892. (With Charles Earle.) *Bull. Amer. Mus. Nat. Hist.*, Vol. vii, Art. i, pp. 1-70.

A Visit to the Exhibit of the New York Academy of Sciences. *Sci. Amer.*, Vol. lxxii, pp. 233-234.

The Hereditary Mechanism and the Search for the Unknown Factors of Evolution. *Amer. Naturalist*, Vol. xxix, pp. 418-439.

Fossil Mammals of the Uinta Basin. Expedition of 1894. *Bull. Amer. Mus. Nat. Hist.*, Vol. vii, Art. ii, pp. 71-105.

Joints in the Vertebrate Skeleton. [Review of "The Origin of the Forms of Joints in the Vertebrate Skeleton," by Gustav Tornier, 1895.] *Science*, N. S., Vol. i, No. 21, May 24, 1895, pp. 581-582.

The History of the Cusps of the Human Molar Teeth. *Intern. Dental Journ.*, pp. 1-26, pl. AA.

Vertebrate Paleontology in the American Museum. *Science*, N. S., Vol. ii, No. 33, Aug. 16, 1895, pp. 178-179.

School of Pure Science. Report of Dean for the Academic Year ending June 30, 1895. *Sixth Annual Report of President Low to the Trustees,* pp. 151-181.

Memorial Tribute to Professor Huxley. *Trans. N. Y. Acad. Sci.,* Vol. xv, pp. 40-50.

Perissodactyls of the Lower Miocene White River Beds. (With J. L. Wortman.) *Bull. Amer. Mus. Nat. Hist.,* Vol. vii, Art. xii, pp. 343-375, pls. viii-xi.

1896

A Student's Reminiscences of Huxley. Biol. Lectures, Marine Biol. Lab., Woods Hole, pp. 29-42.

Titanotheres of the American Museum of Natural History. *Amer. Naturalist,* Vol. xxx, pp. 162-163.

The Corner-Stones of Learning. [Address on the laying of the Corner-stone of Schermerhorn Hall, Columbia University.] *Program of Dedication of the New Site, Morningside Heights,* May 2, 1896, pp. 43-49.

The Cranial Evolution of Titanotherium. *Bull. Amer. Mus. Nat. Hist.,* Vol. viii, Art. ix, pp. 157-197.

The Aim and Method of Science Study in Schools below the College. Biological Work in the High Schools. *Regents Bulletin,* No. 36, pp. 62-64.

Dentition of Lemurs and the Systematic Position of Tarsius. *Science,* N. S., Vol. iv, No. 99, Nov. 20, 1896, pp. 745-747.

Ontogenic and Phylogenic Variation. *Science,* N. S., Vol. iv, No. 100, Nov. 27, 1896, pp. 786-789.

Preliminary Plan for the Prosecution of the Work of the Zoological Society (with C. Grant La Farge & Andrew H. Green), pp. 3-10 of *N. Y. Zool. Soc. Reports on Site of Garden.*

1897

Lambdotherium not related to Palæosyops or the Titanotheres. *Amer. Naturalist,* Vol. xxxi, pp. 55-57.

Goode as a Naturalist. *Science,* N. S., Vol. v, No. 114, March 5, 1897, pp. 373-378.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *1st Ann. Rept. N. Y. Zool. Soc.,* pp. 23-25.

The Origin of the Teeth of the Mammalia. *Science,* N. S., Vol. v, No. 119, April 9, 1897, pp. 576-577.

The Ganodonta or Primitive Edentates with Enameled Teeth. *Science,* N. S., Vol. v, No. 120, April 16, 1897, pp. 611-612.

Edward D. Cope. *Science,* N. S., Vol. v, No. 123, May 7, 1897, pp. 705-717.

Homologies and Nomenclature of the Elements of the Molar Teeth. *Science,* N. S., Vol. vi, No. 142, Sept. 17, 1897, p. 436.

Organic Selection. *Science,* N. S., Vol. vi, No. 146, Oct. 15, 1897, pp. 583-587.

The Huerfano Lake Basin, Southern Colorado, and its Wind River and Bridger Fauna. *Bull. Amer. Mus. Nat. Hist.,* Vol. ix, Art. xxi, pp. 247-258.

The Limits of Organic Selection. *Amer. Naturalist,* Vol. xxxi, pp. 944-951.

Wind River and Bridger Beds in the Huerfano Lake Basin. *Amer. Naturalist,* Vol. xxxi, pp. 966-968.

Reconstruction of Phenacodus primævus, the most primitive Ungulate. *Amer. Naturalist,* Vol. xxxi, p. 980.

Tritubercuły: A Review Dedicated to the Late Professor Edward D. Cope. *Amer. Naturalist,* Vol. xxxi, pp. 993-1016.

Zoology at Columbia. *Columbia Univ. Bull.,* No. xviii, pp. 17-26.

1898

The Biological Problems of To-day: Palæontological Problems. *Science,* N. S., Vol. vii, No. 162, Feb. 4, 1898, pp. 145-147.

Palæontological Notes. *Science,* Vol. vii, No. 162, Feb. 4, 1898, pp. 164-165.

[Origin of the Mammalia.] *Science,* N. S., Vol. vii, No. 162, Feb. 4, 1898, pp. 176-178.

Preface to "Fossil Vertebrates in the American Museum of Natural History." Vol. i, pp. iii-vi.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *2nd Ann. Rept. N. Y. Zool. Soc.,* pp. 23-39.

A Complete Skeleton of Teleoceras fossiger. Notes on the Growth and Sexual Characters of this Species. *Bull. Amer. Mus. Nat. Hist.,* Vol. x, Art. iv, pp. 51-59, pls. iv, iv*a*.

A Placental Marsupial. *Science,* N. S., Vol. vii, No. 170, April 1, 1898, pp. 454-456.

A Complete Skeleton of Coryphodon radians. Notes upon the Locomotion of this Animal. *Bull. Amer. Mus. Nat. Hist.,* Vol. x, Art. vi, pp. 81-91, pl. x.

The Extinct Rhinoceroses. *Mem. Amer. Mus. Nat. Hist.,* Vol. i, Pt. iii, pp. 75-164, pls. xii*a*-xx.

A Complete Skeleton of Teleoceras, the True Rhinoceros from the Upper Miocene of Kansas. *Science,* N. S., Vol. vii, No. 173, April 22, 1898, pp. 554-557.

The Origin of the Mammalia [I]. *Amer. Naturalist,* Vol. xxxii, pp. 309-334.

Remounted Skeleton of Phenacodus primævus. Comparison with Euprotogonia. *Bull. Amer. Mus. Nat. Hist.,* Vol. x, Art. ix, pp. 159-164, pl. xii.

Evolution of the Amblypoda, Part I. Taligrada and Pantodonta. *Bull. Amer. Mus. Nat. Hist.,* Vol. x, Art. xi, pp. 169-218.

The New York Zoological Park. *Science,* N. S., Vol. vii, No. 179, June 3, 1898, pp. 759-764.

Additional Characters of the Great Herbivorous Dinosaur Camarasaurus. *Bull. Amer. Mus. Nat. Hist.,* Vol. x, Art. xii, pp. 219-233.

Models of Extinct Vertebrates. *Science,* N. S., Vol. vii, No. 182, June 24, 1898, pp. 841-845.

Wasatch and Bridger Beds in the Huerfano Lake Basin. *Proc. Amer. Assoc. Adv. Sci.,* Vol. xlvi, pp. 205-206.

[Abstr.] Modification and Variation, and the Limits of Organic Selection. *Proc. Amer. Assoc. Adv. Sci.,* Vol. xlvi, p. 239.

Senff Zoological Expedition to the Nile Valley. *Science,* N. S., Vol. viii, No. 199, Oct. 21, 1898, pp. 541-542.

1899

Frontal Horn on Aceratherium incisivum. Relation of this Type to Elasmotherium. *Ann. N. Y. Acad. Sci.,* Vol. xi, p. 487.

On Some Additional Characters of Diplodocus. *Ann. N. Y. Acad. Sci.,* Vol. xi, p. 487.

Habits of Thylacoleo. *Amer. Naturalist,* Vol. xxxiii, pp. 174-175.

Vertebrate Palæontology. [Review of "Outlines of Vertebrate Palæontology for Students of Zoology," by A. Smith Woodward.] *Natural Science,* Vol. xiv, No. 84, pp. 156-159.

Origin of Mammals. *Proc. 4th Intern. Cong. Zool.,* 1899, pp. 70-71; 413-419.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *3rd Ann. Rept. N. Y. Zool. Soc.,* May 1, 1899, pp. 25-38.

The International Catalogue of Scientific Literature. (With J. McK. Cattell and R. S. Woodward.) *Science,* N. S., Vol. x, No. 241, Aug. 11, 1899, pp. 165-167.

[International Catalogue of Scientific Literature]: K. Paleontology: L. Zoology. *Science,* N. S., Vol. x, No. 241, Aug. 11, 1899, pp. 170-171.

Recent Zoopaleontology. *Science,* N. S., Vol. x, No. 250, Oct. 13, 1899, pp. 538-539.

A Complete Mosasaur Skeleton, Osseous and Cartilaginous. *Mem. Amer. Mus. Nat. Hist.,* Vol. i, Pt. iv, pp. 167-189, pls. xxi-xxiii.

A Skeleton of Diplodocus. *Mem. Amer. Mus. Nat. Hist.,* Vol. i, Pt. v, pp. 191-214, pls. xxiv-xxviii.

Fore and Hind Limbs of Carnivorous and Herbivorous Dinosaurs from the Jurassic of Wyoming. *Bull. Amer. Mus. Nat. Hist.,* Vol. xii, Art. xi, pp. 161-172.

On Pliohyrax Kruppi Osborn, a Fossil Hyracoid, from Samos, Lower Pliocene, in the Stuttgart Collection. A New Type, and the First Known Tertiary Hyracoid. *Proc. 4th Intern. Congr. Zool.,* 1899, pp. 172-173.

Restoration of Extinct Vertebrates, from the American Museum of Natural History. *Proc. 4th Intern. Congr. Zool.*, 1899, p. 174.

1900

Intercentra and Hypapophyses in the Cervical Region of Mosasaurs, Lizards and Sphenodon. *Amer. Naturalist,* Vol. xxxiv, pp. 1-7.

A Glacial Pot-hole in the Hudson River Shales near Catskill, N. Y. *Amer. Naturalist,* Vol. xxxiv, pp. 33-36.

Recent Zoopaleontology. *Science,* N. S., Vol. xi, No. 264, Jan. 19, 1900, pp. 115-116.

The Angulation of the Limbs of Proboscidea, Dinocerata, and Other Quadrupeds in Adaptation to Weight. *Amer. Naturalist,* Vol. xxxiv, pp. 89-94.

The Geological and Faunal Relations of Europe and America during the Tertiary Period and the Theory of the Successive Invasions of an African Fauna. *Science,* N. S., Vol. xi, No. 276, Apr. 13, 1900, pp. 561-574.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *4th Ann. Rept. N. Y. Zool. Soc.,* pp. 27-41.

[Address of Welcome at the Opening of the New York Zoological Park.] *4th Ann. Rept. N. Y. Zool. Soc.,* pp. 76-78.

Progress of the New York Zoological Park. *Science,* N. S., Vol. xi, No. 286, June 22, 1900, pp. 963-965.

The International Catalogue of Scientific Literature. *Science,* N. S., Vol. xii, No. 290, July 20, 1900, p. 113.

Correlation Between Tertiary Mammal Horizons of Europe and America. *Ann. N. Y. Acad. Sci.,* Vol. xiii, pp. 1-72.

The Eighth International Geological Congress at Paris. *Science,* N. S., Vol. xii, No. 299, Sept. 21, 1900, pp. 440-442.

Reconsideration of the Evidence for a Common Dinosaur-Avian Stem in the Permian. *Amer. Naturalist,* Vol. xxxiv, pp. 777-799.

Recent Zoopaleontology. *Science,* N. S., Vol. xii, No. 307, Nov. 16, 1900, pp. 767-769.

Origin of the Mammalia, III. Occipital Condyles of Reptilian Tri-partite Type. *Amer. Naturalist,* Vol. xxxiv, pp. 943-947.

Phylogeny of the Rhinoceroses of Europe. *Bull. Amer. Mus. Nat. Hist.,* Vol. xiii, Art. xix, pp. 229-267.

Oxyæna and Patriofelis Restudied as Terrestrial Creodonts. *Bull. Amer. Mus. Nat. Hist.,* Vol. xiii, Art. xx, pp. 269-281.

Work in the Mammals. *Proc. Amer. Phil. Soc. Memorial Volume I,* pp. 296-303.

1901

The Recent Progress of Vertebrate Palæontology in America. *Science,* N. S., Vol. xiii, No. 315, Jan. 11, 1901, pp. 45-49.

The Attitude of the State Toward Scientific Investigation. *Science,* N. S., Vol. xiii, No. 316, Jan. 18, 1901, pp. 81-85.

Recent Progress in Paleontology. *Science,* N. S., Vol. xiii, No. 335, May 31, 1901, pp. 872-873.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *5th Ann. Rept. N. Y. Zool. Soc.,* pp. 33-42.

Fore and Hind Limbs of Sauropoda from the Bone Cabin Quarry. (With Walter Granger.) *Bull. Amer. Mus. Nat. Hist.,* Vol. xiv, Art. xiii, pp. 199-208.

Mémoires présentés au Congrès de Paris. *Comptes Rendus Congrès Géol. Intern., viiie Session,* Fasc. i, pp. 353-356, 357-363.

Professor Fraas on the Aqueous vs. Æolian Depositions of the White River Oligocene of S. Dakota. [Unsigned.] *Science,* N. S., Vol. xiv, No. 345, Aug. 9, 1901, pp. 210-212.

Recent Zoopaleontology. *Science,* N. S., Vol. xiv, No. 348, Aug. 30, 1901, pp. 330-331.

Recent Zoopaleontology. *Science,* N. S., Vol. xiv, No. 352, Sept. 27, 1901, pp. 498-499.

[Review of J. B. Hatcher's Memoir on Diplodocus Marsh in Mem. Carnegie Mus., Vol. I.] *Science,* N. S., Vol. xiv, No. 353, Oct. 4, 1901, pp. 531-532.

Recent Zoopaleontology. *Science,* N. S., Vol. xiv, No. 354, Oct. 11, 1901, pp. 578-580.

Recent Zoopaleontology. *Science,* N. S., Vol. xiv, No. 357, Nov. 1, 1901, pp. 699-700.

1902

Dolichocephaly and Brachycephaly in the Lower Mammals. *Bull. Amer. Mus. Nat. Hist.,* Vol. xvi, Art. vii, pp. 77-89.

The Four Phyla of Oligocene Titanotheres. *Bull. Amer. Mus. Nat. Hist.,* Vol. xvi, Art. viii, pp. 91-109.

Recent Zoopaleontology. *Science,* N. S., Vol. xv, No. 374, Feb. 28, 1902, pp. 355-357.

Recent Zoopaleontology. *Science,* N. S., Vol. xv, No. 378, Mar. 28, 1902, p. 514.

Homoplasy as a Law of Latent or Potential Homology. *Amer. Naturalist,* Vol. xxxvi, pp. 259-271.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *6th Ann. Rept. N. Y. Zool. Soc.,* pp. 35-43.

The Law of Adaptive Radiation. *Amer. Naturalist,* Vol. xxxvi, pp. 353-363.

Henri Filhol, Paleontologist. *Science,* N. S., Vol. xv, No. 388, June 6, 1902, p. 912.

American Eocene Primates, and the Supposed Rodent Family Mixodectidæ. *Bull. Amer. Mus. Nat. Hist.,* Vol. xvi, Art. xvii, pp. 169-214.

On Vertebrata of the Mid-Cretaceous of the North West Territory. 1. Distinctive Characters of the Mid-Cretaceous Fauna. *Contr. Canadian Pal.* (4to), Vol. iii, Pt. ii, pp. 1-81, pls. i-xxi.

Recent Zoopaleontology. *Science*, N. S., Vol. xvi, No. 408, Oct. 24, 1902, pp. 673-676.

Recent Zoopaleontology. *Science*, N. S., Vol. xvi, No. 409, Oct. 31, 1902, pp. 713-715.

Recent Zoopaleontology. *Science*, N. S., Vol. xvi, No. 410, Nov. 7, 1902, pp. 749-752.

The Fossil Tree Bridge in the Arizona Petrified Forest. *Science*, N. S., Vol. xvi, No. 416, Dec. 19, 1902, p. 991.

1903

Recent Zoopaleontology. *Science*, N. S., Vol. xvii, No. 421, Jan. 23, 1903, pp. 157-158.

Report of Advisory Committee on Paleontology. (With Henry Shaler Williams.) Report of Advisory Committee on Zoology. (With Edmund B. Wilson and W. K. Brooks.) *Year Book Carnegie Inst.*, 1902, pp. 174-184.

Evolution of the Proboscidea in North America. *Science*, N. S., Vol. xvii, No. 424, Feb. 13, 1903, p. 249.

The New York Zoological Park and Aquarium. *Science*, N. S., Vol. xvii, No. 424, Feb. 13, 1903, pp. 265-267.

Recent Zoopaleontology. *Science*, N. S., Vol. xvii, No. 425, Feb. 20, 1903, pp. 312-314.

Recent Zoopaleontology. *Science*, N. S., Vol. xvii, No. 426, Feb. 27, 1903, pp. 356-357.

On the Age of the Belly River Series or Formation in Canada. *Ottawa Naturalist*, Vol. xvi, pp. 227-228.

[As Chairman.] Report of the Executive Committee to the Board of Managers. . . . *7th Ann. Rept. N. Y. Zool. Soc.*, pp. 33-49.

Progress of the Concilium Bibliographicum. *Science*, N. S., Vol. xvii, No. 441, June 12, 1903, pp. 951-952.

Ornitholestes hermanni, a New Compsognathoid Dinosaur from the Upper Jurassic. *Bull. Amer. Mus. Nat. Hist.*, Vol. xix, Art. xii, pp. 459-464.

New York Zoological Park. *Science*, N. S., Vol. xviii, No. 450, Aug. 14, 1903, pp. 218-219.

Glyptotherium texanum, a new Glyptodont, from the Lower Pleistocene of Texas. *Bull. Amer. Mus. Nat. Hist.*, Vol. xix, Art. xvii, pp. 491-494, pl. xliii.

The Reptilian Subclasses Diapsida and Synapsida and the Early History of the Diaptosauria. *Mem. Amer. Mus. Nat. Hist.*, Vol. i, Pt. viii, pp. 451-507.

Recent Zoopaleontology. *Science,* N. S., Vol. xviii, No. 464, Nov. 20, 1903, pp. 665-668.

Recent Zoopaleontology. *Science,* N. S., Vol. xviii, No. 465, Nov. 27, 1903, pp. 699-702.

The Skull of Creosaurus. *Bull. Amer. Mus. Nat. Hist.,* Vol. xix, Art. xxxi, pp. 697-701.

Recent Zoopaleontology. *Science,* N. S., Vol. xviii, No. 469, Dec. 25, 1903, pp. 835-837.

Explorations and Researches of the Department of Vertebrate Paleontology. Preface to "Fossil Vertebrates in the American Museum of Natural History," Vol. ii, pp. iii-xix.

1904

Recent Zoopaleontology. *Science,* N. S., Vol. xix, No. 470, Jan. 1, 1904, pp. 35-36.

Karl Alfred von Zittel. *Science,* N. S., Vol. xix, No. 474, Jan. 29, 1904, pp. 186-188.

Recent Zoopaleontology. *Science,* N. S., Vol. xix, No. 476, Feb. 12, 1904, pp. 271-272.

[Resting Position of the Tasmanian Wolf.] *Nature,* Vol. 69, No. 1799, Apr. 21, 1904, p. 587.

Paleontological Evidence for the Original Tritubercular Theory. *Amer. Journ. Sci.,* (4), Vol. xvii, pp. 321-323, pl. xxi.

Recent Advances in our Knowledge of the Evolution of the Horse. *Proc. Amer. Phil. Soc.,* Vol. xliii, No. 176, pp. 156-157.

An Armadillo from the Middle Eocene (Bridger) of North America. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xii, pp. 163-165.

Progress of the Concilium Bibliographicum. *Science,* N. S., Vol. xix, No. 490, May 20, 1904, pp. 803-805.

New Oligocene Horses. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xiii, pp. 167-179, pl. v.

Manus, Sacrum, and Caudals of Sauropoda. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xiv, pp. 181-190.

Teleorhinus browni—A Teleosaur in the Fort Benton. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xxi, pp. 239-240.

New Miocene Rhinoceroses with Revision of Known Species. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xxvii, pp. 307-326.

The Great Cretaceous Fish Portheus molossus Cope. *Bull. Amer. Mus. Nat. Hist.,* Vol. xx, Art. xxxi, pp. 377-381.

1905

The Evolution of the Horse. *Rept. Brit. Assoc. Adv. Sci.,* 74th meeting, pp. 607-608.

Recent Discoveries of Extinct Animals in the Rocky Mountain Region and Their Bearings on the Present Problems of Evolution. *Science,* N. S., Vol. xxi, No. 523, Jan. 6, 1905, p. 28.

Recent Zoopaleontology. *Science,* N. S., Vol. xxi, No. 530, Feb. 24, 1905, pp. 315-316.

Ten Years' Progress in the Mammalian Palæontology of North America. *Comptes rendus, 6me Congrès Intern. Zool.,* 1904, pp. 86-113, pls. i-xv.

Evolution of the Horse. Recent Studies and Discoveries. *Comptes rendus, 6me Congrès Intern. Zool.,* 1904, p. 282.

History of a White Rhinoceros Skull. *Nature,* Vol. 72, No. 1858, June 8, 1905, p. 127.

Recent Vertebrate Paleontology. Fossil Mammals of Mexico. *Science,* N. S., Vol. xxi, No. 546, June 16, 1905, pp. 931-932.

The Ideas and Terms of Modern Philosophical Anatomy. *Science,* N. S., Vol. xxi, No. 547, June 23, 1905, pp. 959-961.

The Fossil Arachnida of Bohemia. [Review of "Neue Fische und Reptilien" by Fritsch.] *Science,* N. S., Vol. xxii, No. 550, July 14, 1905, p. 57.

The Classification of the Reptilia. *Ann. N. Y. Acad. Sci.,* Vol. xvi, pp. 302-303.

Recent Vertebrate Paleontology. *Science,* N. S., Vol. xxii, No. 554, Aug. 11, 1905, pp. 188-189.

Skull and Skeleton of the Sauropodous Dinosaurs, Morosaurus and Brontosaurus. *Science,* N. S., Vol. xxii, No. 560, Sept. 22, 1905, pp. 374-376.

Tyrannosaurus and Other Cretaceous Carnivorous Dinosaurs. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxi, Art. xiv, pp. 259-265.

Origin and History of the Horse. Address before the New York Farmers, Dec. 19, 1905, pp. 1-16.

1906

Mountain Goat Hunting with the Camera. *10th Ann. Rept. N. Y. Zool. Soc.,* pp. 217-233.

The Skeleton of Brontosaurus and Skull of Morosaurus. *Nature,* Vol. 73, No. 1890, Jan. 18, 1906, pp. 282-284.

The Seven Factors of Education. *Educational Review,* Vol. xxxii, pp. 56-82.

Recent Vertebrate Paleontology. *Science,* N. S., Vol. xxiv, No. 602, July 13, 1906, pp. 55-57.

Milk Dentition of the Hyracoid Saghatherium from the Upper Eocene of Egypt. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxii, Art. xiii, pp. 263-266.

Tyrannosaurus, Upper Cretaceous Carnivorous Dinosaur. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxii, Art. xvi, pp. 281-296.

Recent Vertebrate Paleontology. *Science,* N. S., Vol. xxiv, No. 606, Aug. 10, 1906, pp. 184-185.

The Causes of Extinction of Mammalia. *Amer. Naturalist,* Vol. xl, pp. 769-795; 829-859.

[Letter Relating to Secretaryship of Smithsonian Institution.] *Science,* N. S., Vol. xxiv, No. 625, Dec. 21, 1906, pp. 825-826.

1907

The Fayûm Expedition of the American Museum. *Science,* N. S., Vol. xxv, No. 639, Mar. 29, 1907, pp. 513-516.

Tertiary Mammal Horizons of North America. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiii, Art. xi, pp. 237-253.

A Mounted Skeleton of the Columbian Mammoth (Elephas columbi). *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiii, Art. xii, pp. 255-257.

Points of the Skeleton of the Arab Horse. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiii, Art. xiii, pp. 259-263.

A Mounted Skeleton of Naosaurus, a Pelycosaur from the Permian of Texas. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiii, Art. xiv, pp. 265-270.

Concilium Bibliographicum. *Science,* N. S., Vol. xxvi, No. 660, Aug. 23, 1907, pp. 260-261.

Evolution of Mammalian Molar Teeth to and from the Triangular Type. 8vo, The Macmillan Company, New York and London, 250 pp. (Edited by Dr. W. K. Gregory.)

Evolution as it Appears to the Paleontologist. *Science,* N. S., Vol. xxvi, No. 674, Nov. 29, 1907, pp. 744-749.

Foreword to the Monographs on Vertebrate Paleontology. [Preface to "The Ceratopsia" by J. B. Hatcher and R. S. Lull.] *Monographs, U. S. Geol. Survey,* Vol. xlix, pp. xiii-xxvi.

[Abstr.] The Reclassification of the Mammalia. *Ann. N. Y. Acad. Sci.,* Vol. xvii, pp. 611-613.

1908

The Four Inseparable Factors of Evolution. Theory of their Distinct and Combined Action in the Transformation of the Titanotheres, an Extinct Family of Hoofed Animals in the Order Perissodactyla. *Science,* N. S., Vol. xxvii, No. 682, Jan. 24, 1908, pp. 148-150.

[As Chairman.] Report of the Executive Committee to the Board of Managers. *12th Ann. Rept. N. Y. Zool. Soc.,* pp. 29-39.

Morris K. Jesup. *Science,* N. S., Vol. xxvii, No. 684, Feb. 7, 1908, pp. 235-236.

New Fossil Mammals from the Fayûm Oligocene, Egypt. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiv, Art. xvi, pp. 265-272.

Explorations and Researches of the Department of Vertebrate Palæontology. (With W. D. Matthew.) Preface to "Fossil Vertebrates in the American Museum of Natural History," Vol. iii, pp. iii-viii.

Coincident Evolution Through Rectigradations. *Science,* N. S., Vol. xxvii, No. 697, May 8, 1908, pp. 749-752.

[As President.] Thirty-ninth Annual Report of the Trustees of the American Museum of Natural History [for the year 1907.] 120 pp.

A Paleontological Trip to Northwestern Nebraska. *Ann. N. Y. Acad. Sci.,* Vol. xviii, pp. 351-352.

New or Little Known Titanotheres from the Eocene and Oligocene. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxiv, Art. xxxii, pp. 599-617.

1909

Cenozoic Mammal Horizons of Western North America. With Faunal Lists of the Tertiary Mammalia of the West by William Diller Matthew. *Bull.* 361 *U. S. Geol. Survey,* pp. 1-138.

[As Chairman.] Report of the Executive Committee to the Board of Managers. *13th Ann. Rept. N. Y. Zool. Soc.,* pp. 31-43.

Darwin Celebrations in the United States. *Nature,* Vol. 80, No. 2055, Mar. 18, 1909, pp. 72-73.

Life and Works of Darwin. *Pop. Sci. Monthly,* Vol. lxxiv, pp. 315-343.

Darwin and Palæontology, in "Fifty Years of Darwinism," 8vo, Henry Holt & Co., New York, pp. 209-250.

Geological Correlation Through Vertebrate Paleontology by International Coöperation. Correlation Bull. No. 1. Plan and Scope. (With Dr. W. D. Matthew.) *Ann. N. Y. Acad. Sci.,* Vol. xix, pp. 41-44.

[As President.] Fortieth Annual Report of the Trustees of the American Museum of Natural History for the Year 1908. 118 pp.

The Epidermis of an Iguanodont Dinosaur. *Science,* N. S., Vol. xxix, No. 750, May 14, 1909, pp. 793-795.

To the Philosophic Zoölogist. *Science,* N. S., Vol. xxix, No. 753, June 4, 1909, pp. 895-896.

The Feeding Habits of Mœritherium and Palæomastodon. *Nature,* Vol. 81, No. 2074, July 29, 1909, pp. 139-140.

Acceptance of the Portrait of Darwin. *Ann. N. Y. Acad. Sci.,* Vol. xix, pp. 21-22.

The Upper Cretaceous Iguanodont Dinosaurs. *Nature,* Vol. 81, No. 2075, Aug. 5, 1909, pp. 160-162.

New Carnivorous Mammals from the Fayûm Oligocene, Egypt. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxvi, Art. xxviii, pp. 415-424.

1910

History, Plan and Scope of the American Museum of Natural History. 4to, New York, 176 pp.

Address of Welcome at Commemoration of the Founding of the American Museum of Natural History. Unveiling of the Statue of Morris K. Jesup. *Amer. Mus. Journ.,* Vol. x, pp. 60-67.

The Paleontologic Correlation Through the Bache Fund. *Science,* N. S., Vol. xxxi, No. 794, Mar. 18, 1910, pp. 407-408.

Correlation of the Cenozoic Through its Mammalian Life. *Journ. Geol.,* Vol. xviii, pp. 201-215.

[As President.] Forty-first Annual Report of the Trustees of the American Museum of Natural History for the Year 1909. 131 pp.

Paleontologic Evidences of Adaptive Radiation. *Pop. Science Monthly,* Vol. lxxvii, pp. 77-81.

The Age of Mammals in Europe, Asia, and North America. 8vo, The Macmillan Company, New York, 635 pp.

[Abstr.] A Means of Estimating the Age of the Mastodon and Other Proboscidea. Separates issued in 1910. *Proc. 7th Intern. Congr. Zool.*, 1907, pp. 782-784.

Huxley on Education. *Columbia Univ. Quart.*, Vol. xiii, pp. 25-38.

1911

A Dinosaur Mummy. *Amer. Mus. Journ.*, Vol. xi, pp. 7-11.

[As President.] Forty-second Annual Report of the Trustees of the American Museum of Natural History for the Year 1910. 144 pp.

"Mutations" of Waagen and "Mutations" of De Vries or [and] "Rectigradations" of Osborn. *Science*, N. S., Vol. xxxiii, No. 844, Mar. 3, 1911, p. 328.

Growth of the Building of the American Museum of Natural History. (With the Administrative Staff.) Roy. 4to, New York, 23 pp.

Biological Conclusions drawn from the Study of the Titanotheres. *Science*, N. S., Vol. xxxiii, No. 856, May 26, 1911, pp. 825-828.

Palæontology. *Encyclopædia Brittanica* (11th ed.), Vol. xx, pp. 579-591, pls. i-ii.

The Museum of the Future. *Amer. Mus. Journ.*, Vol. xi, pp. 223-225.

1912

Darwin's Theory of Evolution by the Selection of Minor Saltations. *Amer. Naturalist*, Vol. xlvi, pp. 76-82.

[As President.] Forty-third Annual Report of the Trustees of the American Museum of Natural History for the Year 1911. 173 pp.

First Use of the Word "Genotype." *Science*, N. S., Vol. xxxv, No. 896, Mar. 1, 1912, pp. 340-341.

Phylogeny and Ontogeny of the Horns of Mammals. *Science*, Vol. xxxv, No. 902, Apr. 12, 1912, pp. 595-596.

Skull Measurements in Man and the Hoofed Mammals. *Science*, N. S., Vol. xxxv, No. 902, Apr. 12, 1912, p. 596.

Preservation of the World's Animal Life. *Amer. Mus. Journ.*, Vol. xii, pp. 123-124.

The Continuous Origin of Certain Unit Characters as Observed by a Palæontologist. *Harvey Soc. Volume*, 7th ser., pp. 153-204.

[Abstr.] Zoogeographical Relations of North Africa in the Upper Eocene. *Proc. 7th Intern. Congr. Zool.*, 1907, p. 740.

Correlation and Paleogeography. *Bull. Geol. Soc. Amer.*, Vol. xxiii, pp. 232-256.

Scientific Worthies. xxviii.—Dr. Alfred Russel Wallace. *Nature*, Vol. 89, No. 2224, June 13, 1912, pp. 367-370.

Tetraplasy, the Law of the Four Inseparable Factors of Evolution. *Journ. Acad. Nat. Sci. Phila.*, (2), Vol. xv, pp. 275-309.

Crania of Tyrannosaurus and Allosaurus. *Mem. Amer. Mus. Nat. Hist.*, N. S., Vol. i, Pt. i, pp. 1-30, pls. i-iv, figs. 1-27.

Integument of the Iguanodont Dinosaur Trachodon. *Mem. Amer. Mus. Nat. Hist.,* N. S., Vol. i, Pt. ii, pp. 33-54, pls. v-x, figs. 1-13.

Craniometry of the Equidæ. *Mem. Amer. Mus. Nat. Hist.,* N. S., Vol. i, Pt. iii, pp. 57-100, figs. 1-17.

The State Museum and State Progress. *Science,* N. S., Vol. xxxvi, No. 929, Oct. 18, 1912, pp. 493-504.

Men of the Old Stone Age. With an Account of a Motor Tour Through the Principal Cavern Regions of Southwestern Europe. *Amer. Mus. Journ.,* Vol. xii, pp. 279-295.

1913

[As President.] Forty-fourth Annual Report of the Trustees of the American Museum of Natural History for the Year 1912. 208 pp.

Biographical Memoir of Joseph Leidy, 1823-1891. *Biographical Memoirs National Acad. Sci.,* Vol. vii, pp. 339-396.

Tyrannosaurus, Restoration and Model of the Skeleton. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxii, Art. iv, pp. 91-92, pls. iv-vi.

The Horse Past and Present in the American Museum of Natural History. Issued by the American Museum, May 6, 1913, 4to, 37 pp.

The Museum and Nature Study in the Public Schools. (With George H. Sherwood.) *Miscel. Pub. Amer. Mus. Nat. Hist.,* No. 3, 1913, 13 pp.

Eomoropus, an American Eocene Chalicothere. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxii, Art. xiv, pp. 261-274.

Lower Eocene Titanotheres. Genera Lambdotherium, Eotitanops. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxii, Art. xxi, pp. 407-415.

The Skull of Bathyopsis, Wind River Uintathere. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxii, Art. xxii, pp. 417-420.

Alfred Russel Wallace. *Pop. Sci. Monthly,* Vol. lxxxiii, pp. 523-537.

A Great Naturalist, Alfred Russel Wallace, 1823-1913. *Amer. Mus. Journ.,* Vol. xiii, pp. 331-333.

1914

[As President.] Forty-fifth Annual Report of the Trustees of the American Museum of Natural History for the Year 1913. 192 pp.

Close of the Cretaceous and Opening of Eocene Time in North America. *Bull. Geol. Soc. Amer.,* Vol. xxv, pp. 321-323.

Recent Results in the Phylogeny of the Titanotheres. *Bull. Geol. Soc. Amer.,* Vol. xxv, pp. 403-405.

[Abstr.] New Methods of Restoring Eotitanops and Brontotherium. *Bull. Geol. Soc. Amer.,* Vol. xxv, p. 406.

Restoration of the World Series of Elephants and Mastodons. *Bull. Geol. Soc. Amer.,* Vol. xxv, pp. 407-410.

The Broom Fossil Reptile Collection. *Amer. Mus. Journ.,* Vol. xiv, pp. 137-138.

1915

[As President.] Forty-sixth Annual Report of the Trustees of the American Museum of Natural History for the Year 1914. 192 pp.

Origin of Single Characters as Observed in Fossil and Living Animals and Plants. *Amer. Naturalist,* Vol. xlix, pp. 193-240.

Eberhard Fraas. *Science,* N. S., Vol. xli, No. 1059, April 16, 1915, pp. 571-572.

Review of the Pleistocene of Europe, Asia, and Northern Africa. *Ann. N. Y. Acad. Sci.,* Vol. xxvi, pp. 215-315, 20 text figs.

Close of Jurassic and Opening of Cretaceous Time in North America. Introduction to Symposium. *Bull. Geol. Soc. Amer.,* Vol. xxvi, pp. 295-302, 1 text fig.

The Origin of New Adaptive Characters. [A Reply.] *Nature,* Vol. 96, No. 2402, Nov. 11, 1915, pp. 284-285.

Men of the Old Stone Age, Their Environment, Life, and Art. 8vo, Charles Scribner's Sons, New York, 545 pp., pls. i-viii, 268 text figs.

1916

[As President.] Forty-seventh Annual Report of the Trustees of the American Museum of Natural History for the Year 1915. 194 pp.

The Museum as the New Force in Public School Development. *Journ. National Inst. Social Sci.,* Vol. ii (1916), pp. 155-157 (abbreviated).

Gustav Schwalbe. *Science,* N. S., Vol. xliv, No. 1125, July 21, 1916, p. 97.

Two New Oligocene Titanotheres. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxv, Art. xl, pp. 721-723.

1917

Skeletal Adaptations of Ornitholestes, Struthiomimus, Tyrannosaurus. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxv, Art. xliii, pp. 733-771, pls. xxiv-xxvi, text figs. 1-21.

Application of the Laws of Action, Reaction and Interaction in Life Evolution. *Proc. National Acad. Sci.,* Vol. iii, pp. 7-9.

[Abstr.] Skeleton and Restoration of Camarasaurus. (With C. C. Mook.) *Bull. Geol. Soc. Amer.,* Vol. xxviii, p. 215.

[As President.] Forty-eighth Annual Report of the Trustees of the American Museum of Natural History for the Year 1916. 235 pp.

The "Ostrich" Dinosaur and the "Tyrant" Dinosaur. *Amer. Mus. Journ.,* Vol. xvii, pp. 5-13, 9 text figs.

Heritage and Habitus. *Science,* N. S., Vol. xlv, No. 1174, June 29, 1917, pp. 560-561.

The Museum as the New Force in Public School Development. *Journ. National Education Assoc.,* Vol. i, pp. 735-736.

The Daniel Giraud Elliot Medal. *Science,* N. S., Vol. xlvi, No. 1178, July 27, 1917, pp. 85-86.

Biocharacters as Separable Units of Organic Structure. *Amer. Naturalist,* Vol. li, pp. 449-456.

Algonkian Bacteria and Popular Science. *Science,* N. S., Vol. xlvi, No. 1192, Nov. 2, 1917, pp. 432-434. See also *Science,* N. S., Vol. xlvi, No. 1184, Sept. 7, 1917, pp. 238-239.

The Crocker Land Expedition Home. *Amer. Mus. Journ.,* Vol. xvii, p. 365.

The Origin and Evolution of Life on the Theory of Action, Reaction, and Interaction. 8vo, Charles Scribner's Sons, New York, 322 pp., frontispiece, 135 text figs.

Native Grasses of Australia. *Nature,* Vol. 100, No. 2505, Nov. 1, 1917, p. 165.

1918

Observations on the Skeleton of Moropus cooki in the American Museum. *Bull. Geol. Soc. Amer.,* Vol. xxix, pp. 131-133.

A Long-Jawed Mastodon Skeleton from South Dakota and Phylogeny of the Proboscidea. *Bull. Geol. Soc. Amer.,* Vol. xxix, pp. 133-137.

[As President.] Forty-ninth Annual Report of the Trustees of the American Museum of Natural History for the Year 1917. 239 pp.

Equidæ of the Oligocene, Miocene, and Pliocene of North America, Iconographic Type Revision. *Mem. Amer. Mus. Nat. Hist.,* N. S., Vol. ii, Pt. i, 217 pp., 54 pls., 173 text figs.

Nature in the Schools. [Preface to "Free Education in the American Museum of Natural History in Public Schools and Colleges: History and Status in 1917," by George H. Sherwood, Curator.] *Miscel. Pub. Amer. Mus. Nat. Hist.,* No. 10, 1918, pp. 5, 6.

1919

The Proposed Washington-Lafayette School for Boys in France. *School and Soc.,* Vol. viii, pp. 442-444; 471-473; 592-597; 625-629; Vol. ix, pp. 178-184.

Samuel Wendell Williston, 1852-1918. *Journ. Geol.,* Vol. xxvi, pp. 673-689.

Theodore Roosevelt, Naturalist. *Nat. Hist.,* Vol. xix, pp. 9, 10.

[As President.] Fiftieth Annual Report of the Trustees of the American Museum of Natural History for the Year 1918. 237 pp.

[Review.] Zoologica. Scientific Contributions of the New York Zoological Society. Vol. I, 1907-1915. *Science,* N. S., Vol. xlix, No. 1277, June 20, 1919, pp. 592-594.

Samuel Wendell Williston—The Man and the Paleontologist. *Sigma Xi Quart.,* Vol. vii, pp. 2-6.

The Congo Expedition of the American Museum of Natural History—Introduction. *Bull. Amer. Mus. Nat. Hist.,* Vol. xxxix, pp. xv-xxvii.

Seventeen Skeletons of Moropus; Probable Habits of this Animal. *Proc. National Acad. Sci.,* Vol. v, pp. 250-252.

Palaeomastodon, the Ancestor of the Long-Jawed Mastodons Only. *Proc. National Acad. Sci.,* Vol. v, pp. 265, 266.

New Titanotheres of the Huerfano. *Bull. Amer. Mus. Nat. Hist.,* Vol. xli, Art. xv, pp. 557-569, 7 figs.

Characters and Restoration of the Sauropod Genus Camarasaurus Cope—From Type Material in the Cope Collection in the American Museum of Natural History. (With Charles Craig Mook.) *Proc. Amer. Phil. Soc.,* Vol. lviii, pp. 386-396, pl. i.

1920

Reconstruction of the Skeleton of the Sauropod Dinosaur, Camarasaurus Cope (Morosaurus Marsh). (With Charles Craig Mook.) *Proc. National Acad. Sci.,* Vol. v, pp. 15-18.

Sequoia—the Auld Lang Syne of Trees. . . . *Nat. Hist.,* Vol. xix, pp. 599-612.

[As President.] Fifty-first Annual Report of the Trustees of the American Museum of Natural History for the Year 1919. 259 pp.

Proposed Educational Tax in New York. *School and Soc.,* Vol. ix, pp. 589-591.

Renewal of Our Relations with the Scientific Men of Europe. *Science,* N. S., Vol. li, No. 1327, June 4, 1920, pp. 567, 568.

Fourth Year of the Tropical Research Station. *Science,* N. S. Vol. li, No. 1328, June 11, 1920, pp. 585-587.

Scientific Work in the Hawaiian Islands. *Science,* N. S., Vol. li, No. 1329, June 18, 1920, pp. 613, 614.

The Elliot Medal. *Science,* N. S., Vol. li, No. 1330, June 25, 1920, pp. 629, 630.

The Hall of the Age of Man in the American Museum. *Guide Leaflet* No. 52, *Amer. Mus. Nat. Hist.*

Nature in the Schools—Inspiration, Visual Instruction, Observation, Learning. [Foreword to "Free Nature Education . . ." by George H. Sherwood.] *Miscel. Pub. Amer. Mus. Nat. Hist.,* No. 13, pp. 5, 6.

1921

The Evolution, Phlogeny, and Classification of the Proboscidea. *Amer. Mus. Novitates,* No. 1, 15 pp.

Resemblances and Contrasts between Zoologic and Palæontologic Research in Mammalogy. Desirability of Uniform Standards and Systems in Classification, in Description, in Measurement, in Reasoning. *Journ. Mammal.,* Vol. ii, pp. 1-11.

Camarasaurus, Amphicœlias, and Other Sauropods of Cope. (With Charles Craig Mook.) *Mem. Amer. Mus. Nat. Hist.,* N. S., Vol. iii, pp. 247-387, pls. lx-lxxxv.

[As President.] Fifty-second Annual Report of the Trustees of the American Museum of Natural History for the Year 1920. 265 pp.

Third Award of the Daniel Giraud Elliot Medal. *Science,* N. S., Vol. liii, No. 1377, May 20, 1921, pp. 480, 481.

First Appearance of the True Mastodon in America. *Amer. Mus. Novitates,* No. 10, 6 pp.

The First Appearance of the True Mastodon in America. *Science,* N. S., Vol. liv, No. 1388, Aug. 5, 1921, p. 108.

Heads of African Elephants—Disparity in Size between That of the Male and That of the Female. *Nat. Hist.,* Vol. xxi, pp. 244, 245.

The Evolution, Phylogeny, and Classification of the Mastodontoidea. *Bull. Geol. Soc. Amer.,* Vol. xxxii, pp. 327-332.

Objects of the Tropical Research Station. *Zoologica,* Vol. iii, pp. 3-11.

Eugenics—The American and Norwegian Programs. *Science,* N. S., Vol. liv, No. 1403, Nov. 18, 1921, pp. 482-484.

The American Society of Naturalists. *Science,* N. S., Vol. liv, No. 1406, Dec. 9, 1921, p. 576.

Adaptive Radiation and Classification of the Proboscidea. *Proc. National Acad. Sci.,* Vol. vii, pp. 231-234.

Joel Asaph Allen, 1838-1921—An Appreciation. *Nat. Hist.,* Vol. xxi, pp. 513-515.

1922

Search for the Record of Robert Hanham Collyer, M.D. *Science,* N. S., Vol. lv, No. 1412, Jan. 20, 1922, p. 72.

The Lost Foxhall Jaw: Robert Hanham Collyer. *Science,* N. S., Vol. lv, No. 1414, Feb. 3, 1922, p. 128.

The Pliocene Man of Foxhall in East Anglia. *Nat. Hist.,* Vol. xxi, pp. 565-576.

The Dawn Man of Piltdown, Sussex. *Nat. Hist.,* Vol. xxi, pp. 577-590.

William Bateson on Darwinism. *Science,* N. S., Vol. lv, No. 1417, Feb. 24, 1922, pp. 194-197.

The Fifth Year of the Tropical Research Station. *Science,* N. S., Vol. lv, No. 1419, Mar. 10, 1922, pp. 254, 255.

[As Chairman.] Report of the Roosevelt Memorial Commission. *State of New York, Legislative Document,* (1922), No. 48, 25 pp.

The Birth of Sculpture in Southern France. *Nat. Hist.,* Vol. xxii, pp. 27-41.

Hesperopithecus, the First Anthropoid Primate Found in America. *Amer. Mus. Novitates,* No. 37, 5 pp., 3 figs.

[As President.] Fifty-third Annual Report of the Trustees of the American Museum of Natural History for the Year 1921. 259 pp.

Palæontology. *Encyclopædia Britannica* (12th ed.), Vol. xxxii (N. S., Vol. iii), pp. 9-16, pls. i, ii.

Orthogenesis as Observed from Paleontological Evidence Beginning in the Year 1889. *Amer. Naturalist,* Vol. lvi, pp. 134-143.

Our Ancestors Arrive in Scandinavia. *Nat. Hist.,* Vol. xxii, pp. 116-134.

Nature and Religion. *The Churchman,* Vol. cxxv, pp. 12, 13.

Species of American Pleistocene Mammoths, Elephas jeffersonii, New Species. *Amer. Mus. Novitates,* No. 41, 16 pp., 12 figs.

Brittany Four Thousand Years Ago. *Nat. Hist.,* Vol. xxii, pp. 197-212.

Recent Discoveries on the Antiquity of Man. (With Chester A. Reeds.) *Proc. National Acad. Sci.,* Vol. viii, pp. 246, 247.

Hesperopithecus, the Anthropoid Primate of Western Nebraska. *Nature,* Vol. 110, No. 2756, Aug. 26, 1922, pp. 281-283, 2 figs.

Discovery of Cretaceous and Older Tertiary Strata in Mongolia. *Science,* N. S., Vol. lvi, No. 1446, Sept. 15, 1922, pp. 291-293.

Pliocene (Tertiary) and Early Pleistocene (Quaternary) Mammalia of East Anglia, Great Britain, in Relation to the Appearance of Man. *Geol. Mag.,* Vol. lix, pp. 433-441, folding table.

Dibelodon edensis (Frick) of Southern California, Miomastodon of the Middle Miocene, New Genus. *Amer. Mus. Novitates,* No. 49, 4 pp.

Migrations and Affinities of the Fossil Proboscideans of Eurasia, North and South America, and Africa. *Amer. Naturalist,* Vol. lvi, pp. 448-455.

Close of the Age of Mammals. (With H. E. Anthony.) *Journ. Mammal.,* Vol. iii, pp. 219-237.

Old and New Standards of Pleistocene Division in Relation to the Prehistory of Man in Europe. (With Chester A. Reeds.) *Bull. Geol. Soc. Amer.,* Vol. xxxiii, pp. 411-490, 14 figs.

1923

Publication Standards in Vertebrate Palaeontology. *Proc. Biol. Soc. Washington,* Vol. xxxv, pp. 1-16.

Mastodons of the Hudson Highlands. *Nat. Hist.,* Vol. xxiii, pp. 3-24, frontispiece.

The Inspiration of the Teacher. *School and Soc.,* Vol. xvii, p. 379.

[As President.] Fifty-fourth Annual Report of the Trustees of the American Museum of Natural History for the Year 1922. 263 pp.

Baluchitherium grangeri. A Giant Hornless Rhinoceros from Mongolia. *Amer. Mus. Novitates,* No. 78, 15 pp., 9 figs.

Twenty-eight Years of Zoological Society Accomplishment. *27th Ann. Rept. N. Y. Zool. Soc.,* pp. 7-25.

The Extinct Giant Rhinoceros, Baluchitherium, of Western and Central Asia. *Nat. Hist.,* Vol. xxiii, pp. 208-228.

Field Explorations of the American Museum During the Year 1922. *Science,* N. S., Vol. lvii, No. 1485, June 15, 1923, pp. 681-683.

Ancient Fauna of Mongolia Discovered by the Third Asiatic Expedition of the American Museum of Natural History. *Science,* N. S., Vol. lvii, No. 1487, June 29, 1923, pp. 729-732.

Evolution and Religion. 12mo, Charles Scribner's Sons, New York, 21 pp.

Titanotheres and Lophiodonts in Mongolia. *Amer. Mus. Novitates,* No. 91, 5 pp., 2 figs.

A New Genus and Species of Ceratopsia from New Mexico, Pentaceratops sternbergii. *Amer. Mus. Novitates,* No. 93, 3 pp., 1 fig.

Cadurcotherium from Mongolia. *Amer. Mus. Novitates,* No. 92, 2 pp.
Two Lower Cretaceous Dinosaurs of Mongolia. *Amer. Mus. Novitates,* No. 95, 10 pp., 5 figs.
The Explorations of the American Museum of Natural History in China and Mongolia. *Proc. Amer. Phil. Soc.,* Vol. lxii, pp. 90-94.
New Subfamily, Generic and Specific Stages in the Evolution of the Proboscidea. *Amer. Mus. Novitates,* No. 99, 4 pp.
Linnean Classification and Phylogenetic Classification of the Proboscidea. *Palaeontologia Hungarica,* Vol. i, pp. 35-54.

1924

The Significance of Recent Discoveries in Mongolia. *China Journ. Sci. and Arts,* Vol. ii, pp. 39-43.
Discoveries During the Season of 1923 by the Third Asiatic Expedition in Mongolia. *Proc. National Acad. Sci.,* Vol. x, pp. 23, 24.
The Approach to the Immigration Problem Through Science. *Proc. National Immigration Conference. Special Report* No. 26, pp. 44-53.
Joseph Leidy, Founder of Vertebrate Palaeontology in America. *Science,* N. S., Vol. lix, No. 1521, Feb. 22, 1924, pp. 173-176.
The Discovery of an Unknown Continent. *Nat. Hist.,* Vol. xxiv, pp. 133-149.
Leidy and Marsh. (Reply to Charles Schuchert.) *Science,* N. S., Vol. lix, No. 1531, May 2, 1924, p. 399.
[As President.] Fifty-fifth Annual Report of the Trustees of the American Museum of Natural History for the Year 1923. 269 pp.
American Men of the Dragon Bones. Personal Impressions of a Field Trip to Mongolia with the Third Asiatic Expedition. *Nat. Hist.,* Vol. xxiv, pp. 350-365.
Psittacosaurus and Protiguanodon: Two Lower Cretaceous Iguanodonts from Mongolia. *Amer. Mus. Novitates,* No. 127, 16 pp., 9 figs.
Sauropoda and Theropoda of the Lower Cretaceous of Mongolia. *Amer. Mus. Novitates,* No. 128, 7 pp., 7 figs.
Asiatic Expeditions of the American Museum of Natural History. *Nature,* Vol. 114, No. 2866, Oct. 4, 1924, pp. 504-507.
Introduction to "Fossil Man in Spain," by Hugo Obermaier. 8vo, Hispanic Soc. of Amer., New York, pp. ix-xv.
Three New Theropoda, Protoceratops Zone, Central Mongolia. *Amer. Mus. Novitates,* No. 144, 12 pp., 8 figs.
Eudinoceras, Upper Eocene Amblypod of Mongolia. *Amer. Mus. Novitates,* No. 145, 5 pp., 2 figs.
Andrewsarchus, Giant Mesonychid of Mongolia. *Amer. Mus. Novitates,* No. 146, 5 pp., 3 figs.
Cadurcotherium ardynense, Oligocene, Mongolia. *Amer. Mus. Novitates,* No. 147, 4 pp., 3 figs.
Serridentinus and Baluchitherium, Loh Formation, Mongolia. *Amer. Mus. Novitates,* No. 148, 5 pp., 2 figs.

The Elliot Medal for 1924. *Science,* N. S., Vol. lx, No. 1561, Nov. 28, 1924, p. 95.

Parelephas in Relation to Phyla and Genera of the Family Elephantidae. *Amer. Mus. Novitates,* No. 152, 7 pp.

Additional Generic and Specific Stages in the Evolution of the Proboscidea. *Amer. Mus. Novitates,* No. 154, 5 pp.

[As Chairman.] Report and Recommendations of the Roosevelt Memorial Commission. *State of New York, Legislative Document* (1925), No. 40, 27 pp.

1925

The Elephants and Mastodons Arrive in America. *Guide Leaflet* No. 62, *Amer. Mus. Nat. Hist.*

The Daniel Giraud Elliot Medal. *Science,* N. S., Vol. lxi, No. 1581, April 17, 1925, pp. 410, 411.

[As President.] Fifty-sixth Annual Report of the Trustees of the American Museum of Natural History for the Year 1924. 305 pp.

Enduring Recollections [of Thomas Henry Huxley]. *Nature,* Supplement to Vol. 115, No. 2897, May 9, 1925, pp. 726-728.

The Origin of Species as Revealed by Vertebrate Paleontology. *Science,* N. S., Vol. lxi, No. 1585, May 15, 1925, pp. 23, 24.

Reminiscences of Huxley. *North Amer. Review,* Vol. ccxxi, pp. 654-664.

The Origin of Species as Revealed by Vertebrate Palaeontology. *Nature,* Vol. 115, No. 2902, June 13, 1925, pp. 925, 926; No. 2903, June 20, 1925, pp. 961-963.

The Earth Speaks to Bryan. 12mo, Charles Scribner's Sons, New York, 91 pp.

Evolution and Education in the Tennessee Trial. *Science,* N. S., Vol. lxii, No. 1594, July 17, 1925, pp. 43-45.

Final Conclusions on the Evolution, Phylogeny and Classification of the Proboscidea. *Proc. Amer. Phil. Soc.,* Vol. lxiv, pp. 17-35.

Extinct Rhinoceroses of North China. *Nat. Hist.,* Vol. xxv, pp. 522, 523.

Upper Eocene and Lower Oligocene Titanotheres of Mongolia. *Amer. Mus. Novitates,* No. 202, 12 pp.

Mammals and Birds of the California Tar Pools. *Nat. Hist.,* Vol. xxv, pp. 527-543.

The Origin of Species, II.—Distinctions Between Rectigradations and Allometrons. *Proc. National Acad. Sci.,* Vol. xi, pp. 749-752.

1926

[As Chairman.] Annual Report of the Roosevelt Memorial Commission, 1925. *State of New York, Legislative Document* (1926), No. 47, 2 pp.

How to Teach Evolution in the Schools. *School and Soc.,* Vol. xxiii, No. 576, Jan. 9, 1926, pp. 25-31.

The Evolution of Human Races. *Nat. Hist.,* Vol. xxvi, pp. 3-13.

Evolution and the University of Nebraska. *Science,* N. S., Vol. lxiii, No. 1625, Feb. 19, 1926, p. 209.

The Origin of Species, 1859-1925. *Bull. 1, Peabody Mus. Nat. Hist.,* pp. 25-38.

[As Chairman.] The Daniel Giraud Elliot Medal. *Science,* N. S., Vol. lxiii, No. 1630, March 26, 1926, pp. 329, 330.

[As President.] Fifty-seventh Annual Report of the Trustees of the American Museum of Natural History for the Year 1925. 269 pp.

Why Central Asia? *Nat. Hist.,* Vol. xxvi, pp. 263-269.

The Problem of the Origin of Species as it Appeared to Darwin in 1859 and as it Appears to Us Today. *Nature,* Vol. 118, No. 2964, Aug. 21, 1926, pp. 270-273.

Evolution and Religion in Education. Polemics of the Fundamentalist Controversy of 1922 to 1926. 8vo, Charles Scribner's Sons, New York, pp. xiii, 240.

Discoveries in the Gobi Desert by the American Museum Expeditions. *Nature,* Vol. 118, No. 2968, Sept. 20, 1926, pp. 418-420.

Evolution III—The Palaeontological Aspect. *Encyclopædia Britannica* (13th ed.). New Vol. I [New Form, Vols. 29-30], pp. 1073-1075.

[Palæontology.] Mongolia, Palaeontologic Discoveries in. *Encyclopædia Britannica* (13th ed.). New Vol. II [New Form, Vols. 29-30], pp. 940-944.

The Problem of the Origin of Species as it Appeared to Darwin in 1859 and as it Appears Today (A Correction). *Nature,* Vol. 118, No. 2973, Oct. 23, 1926, pp. 591, 592.

Modern Aspects of Evolution. [Review of "Nomogenesis: or Evolution Determined by Law," by Prof. Leo S. Berg.] *Nature,* Vol. 118, No. 2974, Oct. 30, 1926, pp. 617, 618.

La protection de la Grande Faune au Congo Belge. *Bull. Cercle Zool. Congolaise,* Vol. iii, pp. 37-41.

Additional New Genera and Species of the Mastodontoid Proboscidea. *Amer. Mus. Novitates,* No. 238, 16 pp., 12 figs.

A Contemporary of Charles Darwin. *Science,* N. S., Vol. lxiv, No. 1669, Dec. 24, 1926, pp. 623, 624.

1927

Creative Education in the School. *School and Soc.,* Vol. xxv, pp. 55-60.

The Origin of Species, V—Speciation and Mutation. *Amer. Naturalist,* Vol. lxi, pp. 5-42.

J. L. Wortman—A Biographical Sketch. *Nat. Hist.,* Vol. xxvi, pp. 652, 653.

[As Chairman.] Second Annual Report of the Board of Trustees of the New York State Roosevelt Memorial, 1926. *State of New York, Legislative Document* (1927), No. 51, 8 pp.

[As President.] Fifty-eighth Annual Report of the Trustees of the American Museum of Natural History for the Year 1926. 300 pp.

Recent Discoveries Relating to the Origin and Antiquity of Man. *Science,* N. S., Vol. lxv, No. 1690, May 20, 1927, pp. 481-488.

The Origin of Man; a Correction. *Science,* N. S., Vol. lxv, No. 1694, June 17, 1927, p. 597.

The Story of the Bear in the First Printing of Darwin's "Origin of Species." *Science,* N. S. Vol. lxv, No. 1695, July 24, 1927, p. 616.

History of the Earth. *Nat. Hist.,* Vol. xxvii, p. 297.

Fundamental Discoveries of the Last Decade in Human Evolution. *Bull. N. Y. Acad. Medicine,* (2), Vol. iii, pp. 513-521.

Creative Education in School, College, University and Museum. 8vo, Charles Scribner's Sons, New York, pp. viii, 360.

Recent Discoveries in Human Evolution. *Long Island Medical Journ.,* Vol. xxi, pp. 563-567.

Recent Discoveries Relating to the Origin and Antiquity of Man. *Palaeobiologica,* Vol. i, pp. 189-202.

Man Rises to Parnassus. 8vo, Princeton University Press, pp. xx, 217, and plates.

1928

History, Plan and Design of the New York State Roosevelt Memorial. Oblg. 4to., 19 pp., vi pls.

[As Chairman.] Third Annual Report of the Board of Trustees of the New York State Roosevelt Memorial 1927. *State of New York, Legislative Document,* (1928), No. 96, 9 pp.

[Reply to Count Costantini on reception of diploma from Italian Institute of Human Palæontology.] *Eugenical News,* Vol. xiii, pp. 26, 27.

The Vanishing Wild Life of Africa. *Nat. Hist.,* Vol. xxvii, pp. 515-524.

The Influence of Habit in the Evolution of Man and the Great Apes. *Bull. N. Y. Acad. Med.,* (2), Vol. iv, pp. 216-230.

The Influence of Bodily Locomotion in Separating Man from the Monkeys and Apes. *Sci. Monthly,* Vol. xxvi, pp. 385-399.

Mammoths and Man in the Transvaal. *Nature,* Vol. 121, No. 3052, April 28, 1928, pp. 672, 673.

[As President.] Fifty-ninth Annual Report of the Trustees of the American Museum of Natural History for the Year 1927. 308 pp.

Louis Agassiz and the Hall of Fame. *Science,* N. S., Vol. lxvii, No. 1743, May 25, 1928, p. 523.

The Plateau Habitat of the Pro-Dawn Man. *Science,* N. S., Vol. lxvii, No. 1745, June 8, 1928, pp. 570, 571.

Researches and Publications of the Princeton University Expeditions to Patagonia 1896-1899. (Review.) *Science,* N. S., Vol. lxvii, No. 1745, June 8, 1928, p. 575.

Present Status of the Problem of Human Ancestry. *Proc. Amer. Phil. Soc.,* Vol. lxvii, pp. 151-155.

Joel Asaph Allen. In "Dictionary of American Biography," Vol. i.

1929

[As Chairman.] Fourth Annual Report of the Board of Trustees of the New York State Roosevelt Memorial. *State of New York, Legislative Document,* (1929), No. 59, 12 pp.

The Revival of Central Asiatic Life. *Nat. Hist.,* Vol. xxix, pp. 3-16.

Bashford Dean. *Nat. Hist.,* Vol. xxix, pp. 102, 103.

Note on the Geological Age of Pithecanthropus and Eoanthropus. *Science,* N. S., Vol. lxix, No. 1782, Feb. 22, 1929, pp. 216, 217.

Is the Ape-Man a Myth? *Human Biology,* Vol. i, pp. 4-9.

[As President.] Sixtieth Annual Report of the Trustees of the American Museum of Natural History for the Year 1928. 180 pp.

Thomas Jefferson, the Pioneer of American Palæontology. *Science,* N. S., Vol. lxix, No. 1790, Apr. 19, 1929, pp. 410-413.

Embolotherium Gen. Nov., of the Ulan Gochu, Mongolia. *Amer. Mus. Novitates,* No. 353, 20 pp., 11 figs.

Charles Depéret. *Science,* N. S., Vol. lxix, No. 2799, June 21, 1929, pp. 636, 637.

Address of Welcome (to Geological Society of America). *Bull. Geol. Soc. Amer.,* Vol. xl, pp. 79, 80.

Sir E. Ray Lankester, K.C.B., F.R.S. *Nature,* Vol. 124, No. 3122, Aug. 31, 1929, pp. 345, 346.

Interruption of Central Asiatic Exploration by the American Museum of Natural History. *Science,* N. S., Vol. lxx, No. 1813, Sept. 27, 1929, p. 291-294.

Paleontological Monographs of the National Geological Surveys. *Science,* N. S., Vol. lxx, No. 1814, Oct. 4, 1929, pp. 315-317.

Howard Crosby Butler. In "Dictionary of National Biography," Vol. iii.

Ancient Migration Routes of Central Asia. *Science,* N. S., Vol. lxx, No. 1826, Dec. 27, 1929, pp. 638, 639.

The Miocene Gibbon of France and Germany. *Nat. Hist.,* Vol. xxix, p. 670.

New Eurasiatic and American Proboscideans. *Amer. Mus. Novitates,* No. 393, 23 pp., 22 figs.

The Titanotheres of Ancient Wyoming, Dakota, and Nebraska. *Monograph 55, U. S. Geol. Surv.* 2 Vols., 4to, Government Printing Office, Washington.

[As Chairman.] Fifth Annual Report of the Trustees of the New York State Roosevelt Memorial . . . 1929. *State of New York, Legislative Document,* (1930), No. 56, 14 pp.

1930

The Discovery of Tertiary Man. *Science,* N. S., Vol. lxxi, No. 1827, Jan. 3, 1930, pp. 1-7.

The Bermuda Oceanographic Expedition. *N. Y. Zool. Soc. Bull.,* Vol. xxxiii, p. 35.

[As President.] Sixty-first Annual Report of the Trustees of the American Museum of Natural History for the Year 1929. 217 pp.

Biographical Memoir of Edward Drinker Cope, 1840-1897. *Biographical Memoirs, National Acad. Sci.,* Vol. xiii, pp. 125-317.

Renewal of the American Museum Exploration in the Gobi Desert. *Science,* N. S., Vol. lxxi, No. 1845, May 9, 1930, pp. 481-482.

Address . . . The Sixtieth Anniversary of the Founding of the [Metropolitan] Museum. *Bull. Metropolitan Mus. Art,* Vol. xxv, Section II, pp. 6, 7.

The Ancestry of Man. *Nature,* Vol. 125, No. 3159, May 17, 1930, p. 745.

Influence of the Glacial Age on the Evolution of Man. *Bull. Geol. Soc. Amer.,* Vol. xl, pp. 589-595.

Palæontology Versus Genetics. *Science,* N. S., Vol. lxxii, No. 1853, July 4, 1930, pp. 1-3.

A New Method of Deep Sea Observation at First Hand. *Science,* N. S., Vol. lxxii, No. 1854, July 11, 1930, pp. 27, 28.

Fifty-two Years of Research, Observation and Publication, 1877-1929. 8vo, Charles Scribner's Sons, New York, pp. xii, 160.

Ancient Vertebrate Life of Central Asia. In "Livre Jubilaire publié à l'occasion du Centenaire de la Société Géologique de France, 1830-1930," pp. 529-543.

The Inspiration of Nature. *Nat. Hist.,* Vol. xxx, p. 451.

Preface to Volume III of the Bulletin of the Vanderbilt Marine Museum. *Bull. Vanderbilt Marine Mus.,* Vol. iii, p. 3.

Parelephas floridanus from the Upper Pleistocene of Florida Compared with P. jeffersoni. *Amer. Mus. Novitates,* No. 443, 17 pp., 9 figs.

1931

New Conceptions of Species and Genera, and of Classification, Discovered in the Evolution of the Titanotheres. *Journ. Mammal.,* Vol. xii, pp. 1-11.

[As Chairman.] Sixth Annual Report of the Board of Trustees of the New York State Roosevelt Memorial . . . 1930. *State of New York, Legislative Document,* (1931), No. 56, 17 pp.

Coryphodonts of Mongolia, Eudinoceras mongoliensis Osborn, E. kholobolchiensis sp. nov. *Amer. Mus. Novitates,* No. 459, 13 pp., 11 figs.

Palæoloxodon antiquus italicus sp. nov., Final Stage in the Elephas antiquus Phylum. *Amer. Mus. Novitates,* No. 460, 24 pp., 17 figs.

The Shovel-Tuskers, Amebelodontinæ, of Central Asia. (With Walter Granger.) *Amer. Mus. Novitates,* No. 470, 12 pp., 3 figs.

Cope: Master Naturalist. (With the cooperation of Helen Ann Warren.) 8vo, Charles Scribner's Sons, New York, pp. xvi, 740.

[As President.] Sixty-second Annual Report of the Trustees of the American Museum of Natural History for the Year 1930. 208 pp.

Palæontology versus De Vriesianism and Genetics in the Factors of the Evolution Problem. *Science*, N. S., Vol. lxxiii, No. 1899, May 22, 1931, pp. 547-549.

George Fisher Baker—1840-1931. *Nat. Hist.*, Vol. xxxi, pp. 328, 329.

Memorial of William Diller Matthew (with complete bibliography). *Bull. Geol. Soc. Amer.*, Vol. xlii, pp. 55-95.

The Lower Pleistocene Age of Peking Man. *Nat. Hist.*, Vol. xxxi, p. 446.

The Elephant Enamel Method of Measuring Pleistocene Time. Also Stages in the Succession of Fossil Man and Stone Age Industries. (With Edwin H. Colbert.) *Proc. Amer. Phil. Soc.*, Vol. lxx, pp. 187-191.

Arrest of Geologic, Archeologic and Paleontologic Work in Central Asia. *Science*, N. S., Vol. lxxiv, No. 1910, Aug. 7, 1931, pp. 139-142.

Explorations, Researches and Publications of Pierre Teilhard de Chardin, 1911-1931. *Amer. Mus. Novitates*, No. 485, 13 pp., map.

Lindsay Morris Sterling. *Nat. Hist.*, Vol. xxxi, p. 563.

Creative Science Teaching. *Progressive Education*, Vol. viii, pp. 468, 469.

The Principles of Evolution Revealed by Palæontology. *Nature*, Vol. 128, No. 3239, Nov. 28, 1931, pp. 894-897.

New Concept of Evolution Based upon Researches on the Titanotheres and the Proboscideans. *Science*, N. S., Vol. lxxiv, No. 1927, Dec. 4, 1931, pp. 557-559.

[As Chairman.] Seventh Annual Report of the Board of Trustees of the New York State Roosevelt Memorial . . . 1931. *State of New York, Legislative Document*, (1932), No. 56, 24 pp.

1932

The Nine Principles of Evolution Revealed by Palæontology. *Amer. Naturalist*, Vol. lxvi, pp. 52-60.

[As President.] Sixty-third Annual Report of the Trustees of the American Museum of Natural History for the Year 1931. 205 pp.

Platybelodon grangeri, Three Growth Stages, and a New Serridentine from Mongolia. (With Walter Granger.) *Amer. Mus. Novitates*, No. 537, 13 pp., 8 figs.

Coryphodonts and Uintatheres from the Mongolian Expedition of 1930. (With Walter Granger.) *Amer. Mus. Novitates*, No. 552, 16 pp., 18 figs.

Birth Selection versus Birth Control. *Science*, N. S., Vol. lxxvi, No. 1965, Aug. 26, 1932, pp. 173-179.

The "Elephas meridionalis" Stage Arrives in America. *Proc. Colorado Mus. Nat. Hist.*, Vol. xi, No. 1, 5 pp., 2 figs.

Trilophodon cooperi, sp. nov., of Dera Bugti, Baluchistan. *Amer. Mus. Novitiates*, No. 585, 6 pp., 2 figs.

Biological Inductions from the Evolution of the Proboscidea. *Science*, N. S., Vol. lxxvi, No. 1979, Dec. 2, 1932. pp. 501-504.

1933

Recent Revivals of Darwinism. *Science*, N. S., Vol. lxxvii, No. 1991, Feb. 24, 1933, pp. 199-202.

[As Chairman.] Eighth Annual Report of the Board of Trustees of the New York State Roosevelt Memorial, 1932. *State of New York, Legislative Document*, (1933), No. 71, 24 pp.

[As President.] Sixty-fourth Annual Report of the Trustees of the American Museum of Natural History for the Year 1932. 130 pp.

Des principes qui ont présidé à l'évolution biomécanique des Mammifères. *Comptes rendus, Acad. Sci.* (Paris), t. 196, No. 24, pp. 1760-1763.

Serbelodon burnhami, a New Shovel-tusker from California. *Amer. Mus. Novitates*, No. 639, 5 pp., 2 figs.

Aristogenesis, the Observed Order of Biomechanical Evolution. *Proc. National Acad. Sci.*, Vol. xix, pp. 699-703.

Mounted Skeleton of Triceratops elatus. *Amer. Mus. Novitates*, No. 654, 14 pp., 5 figs.

Welcome to the International Geological Congress. *Science*, N. S., Vol. lxxviii, No. 2022, Sept. 29, 1933, pp. 274, 275.

Aristogénèse, le nouveau principe inductif d'évolution biomécanique. *Revue Générale Sci.*, t. xliv, pp. 495-505.

1934

Senescent hypotheses as to the nature and causes of evolution. *Science*, N. S., Vol. lxxix, No. 2052, April 27, 1934, p. 376.

[As Chairman.] Ninth Annual Report of the Board of Trustees of the New York State Roosevelt Memorial, 1933. *State of New York, Legislative Document*, (1934), No. 88, 19 pp.

Aristogenesis, the Creative Principle in the Origin of Species. *Amer. Naturalist*, Vol. lxviii, pp. 193-235.

The National Academy of Sciences . . . Presentation of the Daniel Giraud Elliot Medal and Honorarium for 1931 to the late Dr. Davidson Black. *Science*, N. S., Vol. lxxix, No. 2060, June 22, 1934, pp. 553, 554.

Evolution and Geographic Distribution of the Proboscidea: Moeritheres, Deinotheres and Mastodons. *Journ. Mammal.*, Vol. xv, pp. 177-184.

Primitive Archidiskodon and Palaeoloxodon of South Africa. *Amer. Mus. Novitates*, No. 741, 15 pp., 5 figs.

The Thirty-nine Distinct Lines of Proboscidean Descent, and their Migration into all Parts of the World except Australia. *Proc. Amer. Phil. Soc.*, Vol. lxxiv, pp. 273-285.

The Dual Principles of Evolution. *Science*, N. S., Vol. lxxx, No. 2087, Dec. 28, 1934, pp. 601-605.

1935

The Ancestral Tree of the Proboscidea. Discovery, Evolution, Migration, and Extinction Over a 50,000,000 Year Period. *Proc. National Acad. Sci.*, Vol. xxi, pp. 404-412.

Thomas Jefferson as a Paleontologist. *Science,* N. S., Vol. lxxxii, No. 2136, Dec. 6, 1935, pp. 533-538.

1936

Amynodon mongoliensis from the Upper Eocene of Mongolia. *Amer. Mus. Novitates,* No. 859, 5 pp., 2 figs.

Proboscidea. A Monograph . . . Vol. I, Mœritherioidea, Deinotherioidea, Mastodontoidea. 4to, pp. xl, 802, xii pls., 680 text figs. *The American Museum of Natural History.*

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ALBERT ABRAHAM MICHELSON

1852–1931

BY

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It will probably be generally agreed that the three American physicists whose work has been most epoch-making and whose names are most certain to be frequently heard wherever and whenever in future years the story of physics is told are Benjamin Franklin, Josiah Willard Gibbs, and Albert A. Michelson. And yet the three have almost no characteristics in common. Franklin lives as a physicist because, dilettante though he is sometimes called, mere qualitative interpreter though he actually was, yet it was he who with altogether amazing insight laid the real foundations on which the whole superstructure of electrical theory and interpretation has been erected. Gibbs lives because, profound scholar, matchless analyst that he was, he did for statistical mechanics and for thermodynamics what Laplace did for celestial mechanics and Maxwell did for electrodynamics, namely, made his field a well-nigh finished theoretical structure. Michelson, pure experimentalist, designer of instruments, refiner of techniques, lives because in the field of optics he drove the refinement of measurement to its limits and by so doing showed a skeptical world what far-reaching consequences can follow from that sort of a process, and what new vistas of knowledge can be opened up by it. It was a lesson the world had to learn. The results of learning it are reflected today in the extraordinary recent discoveries in the field of electronics, of radioactivity, of vitamins, of hormones, of nuclear structure, etc. All these fields owe a large debt to Michelson, the pioneer in the art of measurement of extraordinarily minute quantities and effects.

I. MICHELSON, THE MAN

Of all those who take their place in the company of the immortals the world is intensely interested in knowing not merely their accomplishments, but how they got started in the line they followed and what manner of men they were. Not very much of this can be learned from Michelson's writings, much less than from those of most equally famous men, and for that

reason this memoir must take on, to an unusual degree, the character of a personal narrative.

The total volume of Michelson's published work is very small. In an active life as a physicist extending from the age of twenty-five to that of seventy-nine, he wrote two small books that are found in all libraries. The first is entitled "Light Waves and Their Uses", University of Chicago Press, 1903. It represents his Lowell Lectures delivered in 1899. The second is "Studies in Optics", University of Chicago Press, 1927, and consists of a condensed summary of his major researches. These books contain some revealing and quotable passages which are used by Hale [1] and Lemon [2] in interesting and informing articles on Michelson.

His bibliography of scientific papers contains but seventy-eight titles all told, and many of these are abstracts and most of them are quite short articles. Not a few of them are reprintings of the same article in different journals and different languages. One's knowledge of Michelson must be gained, then, more from what he did than from what he said. Also, one must call upon the testimony of those who, like the present writer, lived and worked side by side with him for a quarter-century and more. That testimony will, I think, be unanimous in the judgment that his most outstanding characteristic was his extraordinary honesty, his abhorrence alike of careless, inexact, ambiguous statement, as well as of all deception and misstatement. His was a remarkably clean-cut mind, which left little room for adjustment and compromise.

Everyone knows that he was a remarkably accurate and dependable scientific observer, but not everyone knows how well he succeeded in doing what every scientist should do but which many do not succeed in doing, namely, in carrying over that exceptional dependability into all his relations with his fellows. At one time when he had become the subject of some criticism, one of the critics came to me and to another of Michelson's associates, and asked whether these criticisms were well founded. Our joint reply was, "Don't ask us; ask him. He'll tell you."

[1] Astronomical Society of the Pacific *XLIII*, 175, 1931.
[2] The American Physics Teacher *IV*, 1, 1936.

The critic took the advice and returned with the statement, "He certainly told me." His whole effort seemed to be to see and to state things just as they were. The writer played tennis with him for twenty-five years, and watched him call balls. In doing so he was always just and correct, but never generous either to himself or to his opponent. He did not even fool himself, as most of us do, in the analysis of his own motives. Even when those motives were incorrect from the standpoint of his associates, he stated them frankly and with amazing honesty, in one remarkable instance apologizing for his attitude and expressing regret that he was "built that way." Almost anyone else would have rationalized his conduct into a virtue, and lied both to himself and his critics, as we are now seeing done so continuously and so deplorably in our political life.

I am quite certain that the last thing Professor Michelson would desire would be to have this memoir made merely an eulogy. I am therefore endeavoring to give first as correct a picture as I can of the man as I knew him through more than twenty-five years of intimate association.

If his most outstanding characteristic was his honesty, his second most notable characteristic was the singleness, simplicity, and clarity of his objective—an objective from which he let nothing divert him however great the pressure. He was an intense individualist, he knew what he wanted to do, he had confidence in his ability to do it, and he refused to let anything divert him from it, no matter what other interests had to be sacrificed, or who stood in the way. The result was that he made no pretense of keeping widely informed outside his own field. Indeed, he was always depreciating his own knowledge even of the field of physics, despite the fact that he was quite fond of telling the incident of how he once told G. Stanley Hall that if he wanted to keep a first rate physicist like himself at Clark University he would have to treat him like a first rate physicist.

There is no doubt, too, that in fields other than physics his reactions were sometimes hasty and occasionally purely emotional. This was well illustrated at the time of the blowing up of the Maine. President Harper had asked the historian Van Holst and the ex-navy man and scientist Michelson to address

the assembly of the students at the University of Chicago upon the situation that had been created by that incident. Van Holst counselled caution, delay, and painstaking investigation before any action was taken or even thought of. Michelson was for declaring war at once and immediately taking drastic steps.

But the best illustration of his singleness of purpose is furnished by the early history of the Ryerson Laboratory. From a scientific point of view this consisted very largely of the history of Michelson's individual contributions. Some of the personal sides of that history are worth telling here for the light they throw on Michelson, the man. I first met him at the exercises connected with the dedication of the laboratory at the spring convocation of the year 1894. He had been the commencement speaker, and in his address had emphasized the significance of refinement of measurement for the progress of science—a significance which subsequent years have shown to be vastly greater than even he foresaw, inspired prophet though he was. Incidentally, in that address he used another's words, I think Kelvin's, as to the unlikelihood of future discoveries coming from other work than that involving the sixth place of decimals. He afterwards upbraided himself unmercifully to me for ever having done so.

At the dinner which he gave in the evening of that day to some fifty visiting physicists he was rallied for introducing personal charm as an attribute of the coming six-decimal-place physicist, for with his jet black hair, his attractive hazel eyes, his faultless attire, and his elegant and dignified bearing, he made a striking figure, though his height was not over five feet seven or eight. The next day I attended his first lecture to the group of some six or seven graduate students, who were there for the work of the summer quarter at the University of Chicago. He was himself the graduate department, giving the only graduate course. The impression that was made upon me by that course and by his presentation of the "visibility curves" which had recently been obtained—curves which enabled one by the aid of skillful observing and more skillful analysis to read for the first time the fine structure of spectral lines far beyond the power of

any instrument to reveal it directly to the eye—was memorable. This course, along with about two conversations which I had with him when he came to my room to see how I was getting along with my measurements on the polarization of the light emitted by incandescent surfaces, impressed me with the fact that I was in the presence of one who had a far deeper understanding of optics than any one I had thus far met. Elegance of observational technique, elegance of analysis, elegance of presentation,—these were, I think, the impressions made on all of us younger men who had a chance to see Michelson's experimental work and hear him present it. He always lectured twice a week and quizzed once on the ground covered in the two preceding lectures, and he could cover more ground in an hour than any lecturer I ever heard. The two texts which he relied upon mostly for the material of his lectures, when he was not presenting his own work, were Mascart and Joubert's "Electricity and Magnetism" and Rayleigh's "Sound." The material covered in his lectures embraced the whole fields of electricity, sound, and optics. He did nothing with thermodynamics, to which he had a certain aversion, probably because of its extreme generality and lack of concreteness—I think he greatly underestimated its value and its accomplishment—and while he was sympathetic with the kinetic theory and molecular physics, he incorporated little of this field into his courses. Also, the newer physics,—radioactivity, electronics, and quantum theory—were largely outside the field of his interest, though of the Zeeman effect he made a careful study, both experimental and theoretical, and when X-rays were discovered he stepped aside from his routine, as nearly everyone else did, to try to contribute something to the elucidation of the source and nature of the new phenomenon.

It was probably fortunate for me in my very limited relations with him as pupil (summer of 1894, only) and my long continued relations with him as a subordinate member of his staff, that I had my own problems in which he only assisted me incidentally, and that I was never either his immediate assistant or his collaborator; for at least in those earlier years Professor

Michelson's attempts in Chicago at collaborative work, either with staff members or with graduate students, did not in general turn out very well either from his own point of view or from that of the collaborator. In the case of both of the two staff members with whom in the nineties he tried to do some work in common, difficulties arose, and when one of them left about 1900 he assured me that my "turn would come next." And yet during the next twenty-one years during which I was with him I could not have asked for more considerate and courteous treatment than I uniformly received from Professor Michelson. It is true that on two occasions I thought he was wrong and told him so, but his explanations were so completely straightforward and disarming that I could only laugh and tell him that he was the most honest man I had ever met.

His relations with graduate students during the ten years from 1894 to 1904 tell much the same story. He assigned but few thesis subjects and no small proportion of these turned out none too happily. I think it was in 1905 that he called me to his office and said, "If you can find some other way to handle it I don't want to bother any more with this thesis business. What these graduate students always do with my problems, if I turn them over to them, is either to spoil the problem for me because they haven't the capacity to handle it as I want it handled, and yet they make it impossible for me to discharge them and do the problem myself; or else, on the other hand, they get good results and at once begin to think the problem is theirs instead of mine, when in fact the knowing of what kind of a problem it is worth while to attack is in general more important than the mere carrying out of the necessary steps. So I prefer not to bother with graduate students' theses any longer. I will hire my own assistant by the month, a man who will not think I owe him anything further than to see that he gets his monthly check. You take care of the graduate students in any way you see fit and I'll be your debtor forever." From that time on Professor Michelson assigned very few, if any, thesis problems. And this decision was the correct one for him to make, for he gauged his own qualities and capacities cor-

rectly. He knew what he was best fitted to do, and he did not let anything or anybody deter him from that course. He took no part in general university administrative or instructional problems outside the department of physics. I never saw him in a faculty meeting despite the fact that, in the early days of the University of Chicago, faculty meetings were very important affairs where university policies were very thoroughly threshed out.

His regular departmental routine was as follows: He met his class of graduate students regularly three times a week for two lectures and one quiz. All graduate students took his courses when they were ready for them. His lectures were carefully prepared. They were very condensed, with most of the details left for the students to work out. They were considered hard courses. He worked every day with his personal assistant, and often with the mechanician, in his research laboratory, and about four o'clock he regularly went over to the Quadrangle Club to play tennis or billiards, at both of which he was quite proficient. His evenings he spent at home; for his life with his second wife, Edna Stanton (married in 1900), and their three daughters was an altogether happy one, although his earlier marriage had not in the end turned out successfully.

The foregoing characteristics explain, perhaps, the fact that during his earlier years Michelson acquired the reputation of being somewhat unapproachable, difficult, dictatorial, even inconsiderate. If he possessed these qualities in the earlier part of his life he certainly lost them in the later part, for the mellowing effect of his later years was particularly noteworthy. It was commented upon by all his intimates, as well as by his students. It is shown, too, by the fact that his first wife, from whom he was divorced in 1897 and who was later Mrs. Margaret Hemingway Shepperd, and by whom he had three children, one daughter and two sons (one of whom is at present an ethnologist in the Bureau of American Ethnology of the Smithsonian Institution) wrote me in 1932 that before his death he sent his lawyer to her to ask her forgiveness for any suffering he might have caused her.

II. MICHELSON'S PARENTAGE, CHILDHOOD, AND YOUTH

Albert Abraham Michelson was born at Strelno, then in Germany, a small town near the frontier of Poland, on December 19, 1852. His mother, Rosalie Przlubska, was the daughter of a well known physician, and was left motherless in early youth. In her various duties for the household she met, fell in love with, and married the proprietor of a dry goods shop, a man of forty years, Samuel Michelson. She was then but eighteen years of age. Before 1855 two children had been born, a boy and a girl. Because of the troublous times existing in that year in Poland, they decided to come to America where Samuel Michelson had a sister living in California. They took passage via Panama to San Francisco, and then moved on to the lovely little mountain town in Calaveras County called Murphy's Camp, described by Bret Harte in one of his stories, where Albert's early childhood was spent. The only bits of information I have been able to find regarding childhood influences are contained in the following excerpts from letters to me from the members of his family.

The first Mrs. Michelson writes: "In those mining camps there were many cultivated men seeking a fortune, among them a fine violinist who taught little Albert the violin. In 1886, with Albert Abraham Michelson and our three children, we visited Murphy's Camp and met many of the old miners, but they had no stories to tell me except the love that the child (Albert) had for the violin." Though not a finished musician, Michelson continued to play the violin throughout his life.

The following excerpt from a letter written me by A. A. Michelson's famous author sister, Miriam Michelson, shows how early and how completely the whole Michelson family had broken away from the religion of their race. "Both Albert Michelson's father and mother were born of Jewish parents, yet I should not say that ours was a religious family. I had no religious training whatever. Nor can I recall a religious discussion among us, nor a religious inhibition or compulsion. And I believe this unorthodox viewpoint would have been the case

with both parents and children no matter what religious belief the former might have inherited." Neither in aspect nor characteristic did Michelson ever reveal any racial penchants or prejudices. He apparently had no feelings whatever of that sort.

A third quotation from a letter to me from his son, Truman Michelson, may have a little interest. It reads, "A fact not usually known is that my father was a Mason, enrolled in Washington Lodge N 21 L and AM. He resigned upon going to study in Europe."

As the young Michelson grew older he was sent to San Francisco to school, where "he developed few companionships," but where he lived for several years with the family of the principal of the high school, who later paid him three dollars a month—his first earnings—to keep the physical instruments in order. When Albert was sixteen he went back to the home of his father, who by that time had moved his drygoods business to Virginia City, Nevada, famous because of the history of the Comstock lode and more famous because of the immortality which Mark Twain gave it. The elder Michelson wished his son Albert to enter the Navy, so when, the next year, there was a vacancy in Nevada's quota, Albert took the examination for congressional appointment to Annapolis. He tied with another boy, who through influence got the appointment while Michelson was made alternate, but also given, by the local Congressman, a personal letter to President Grant which it was hoped might enable him to get one of the ten special Presidential appointments at large to the Academy. He obtained his interview with the President, who, however, informed him that he had already exhausted his ten appointments at large. Nevertheless, one of the President's Naval Aids told young Michelson to go over to Annapolis, since there was still a chance of a vacancy through the failure of one of the new appointees who had not yet passed his examination. After three days of waiting at Annapolis this hope failed, and Michelson was just starting back for Washington to try again with the President when the Commandant sent a messenger after him and informed him that the President had given him "an appointment at large."

Since this was the eleventh such appointment Michelson always maintained that his career was started by an illegal act.

His record at the Naval Academy does not appear to have been in any way notable. His first wife writes that "it was not brilliant." The records at the Naval Academy contain merely the following entries:

Ensign A. A. Michelson, U. S. Navy. Born in Poland, December 19, 1852. Died May 9, 1931. Came to U. S. in 1854.
Appointed *Cadet Midshipman* at Naval Academy June 29, 1869.
May 31, 1873, detached from Naval Academy to await orders.
September 18, 1873, ordered to the "Monongahela."
October 31, 1873, detached from "Monongahela."
December 12, 1873, ordered to "Minnesota."
December 23, 1873, transferred to "Roanoke."
August 19, 1874, transferred to North Atlantic Squadron, and joined the "Colorado." Transferred to "Worcester."
October 14, 1874, detached from "Worcester" and ordered to appear before Examining Board.
July 16, 1874, promoted to Ensign.
December 15, 1875, ordered to Naval Academy.
May 22, 1877, ordered to "Constellation" (practice ship).
September 18, 1877, resumed duties Naval Academy. Became teacher and physicist in the capacity of Professor at the U. S. Naval Academy.

The first Mrs. Michelson, however, adds to this mere skeleton the following facts: In the course of his ship cruises young Michelson was one day in London visiting Dickens' recently garlanded tomb in Westminster. The striking appearance of the young naval cadet made a vivid impression upon the young American girl, Margaret McLean Hemingway, who happened to be standing opposite him with her parents. Miss Hemingway was the niece of the wife of Admiral Sampson, who shortly after was detailed to Annapolis as Professor of Physics in the Naval Academy. In December, 1875, Michelson was sent back to the Naval Academy as instructor in physics and chemistry. It was while Miss Hemingway was visiting her uncle and aunt that she at once recognized in the young instructor the midshipman cadet whose "brilliant eyes" had made such an impression upon her as they stood beside Dickens' tomb. They became engaged.

and on April 10, 1877, when she was 18 and he 24, they were married at Mr. Hemingway's summer home in New Rochelle, N. Y. After a summer cruise with the naval cadets, young Michelson and his bride returned to his duties at the Naval Academy.

III. MICHELSON AND THE VELOCITY OF LIGHT

In November of that same year, 1877, while studying, for the purposes of a lecture, the three purely terrestrial determinations of the velocity of light that had thus far been made, one by Fizeau in 1849, one by Cornu in 1872, both by Fizeau's toothed-wheel method, and one in 1862 by Foucault, a slight but, for accuracy, a very vital modification of the Foucault method suggested itself to Michelson, which, to quote his own words, "dispenses with Foucault's concave mirror and permits the use of any distance."

Foucault, and, following him, Newcomb who with the aid of a relatively large congressional appropriation had for some time prior to any work by Michelson been working at a determination of the velocity of light by a modification of Foucault's method, had placed the rotating mirror between the lens and the mirror used to return the beam back to the rotating mirror. In order to get enough light this required the use of a relatively large rotating mirror, and in Foucault's case the distance between the two mirrors was only twenty meters. It is to be remembered, however, that Foucault's apparatus was designed to permit the insertion between the mirrors of a tube filled with water, for his primary purpose was to determine whether the speed of light was greater in air or in water, for this was the crucial problem of his day and this problem he successfully solved. It is true, however, that with his arrangement it was impossible to get enough light to enable the use of a large distance between the two mirrors. Also, when in 1872 Cornu went at a precise, absolute determination he studied carefully and elaborately Foucault's rotating mirror method, and discarded it because he could not extend the intermirror distance to more than thirty meters. Michelson, though only an inexperienced youth of twenty-four, with that quick insight into the vital

elements of an experimental problem which was characteristic of all his design work, saw what other scientists of the highest repute who had studied the rotating mirror method had failed to see, namely, that by simply placing the point (or line) source at the principal focus of the lens so that the beam went out from the lens as a parallel bundle of rays which could be returned on itself as a parallel beam by a plane mirror *placed at any desired distance,* and then using a *small,* rotating mirror placed just in front of the point source, he could use any distance that he wished without any loss of light. This would make Foucault's rotating mirror method altogether comparable with Fizeau's rotating toothed-wheel method for an absolute measurement. Between November, 1877, and March, 1878, he built at an expense of ten dollars, a rotating mirror and using with it a lens which he found in the physics lecture equipment at Annapolis he obtained a displacement of 5 mm., while Foucault had had a displacement of .8 mm. Michelson wrote these results to the editor of the American Journal of Science. This letter takes up half a page of the May issue of 1878, and is Michelson's first publication. At the suggestion of his wife, her father in July, '78, gave him $2,000 for improving the precision of the method, and he was presently using a distance of 700 meters, instead of 20, and getting 133 mm. deflection. As a result of all his early determinations by this technique he obtained the value 299,895 km. per second, a value which he regarded as correct to one part in 10,000.

This problem, with which his career began, was also the one with which it closed. Four years before his death, at the age of seventy-five, he published in the Astrophysical Journal 65, 1-14, 1927, the final mean of the results of his measurement made by sending a beam from Mt. Wilson to Mt. San Antonio, California, and back, 35 km. distant. The method now used, however, is essentially a combination of Fizeau's method and of Foucault's, since now Fizeau's rotating toothed-wheel is replaced by a rotating octagonal mirror, and the time of double transit of the light is the time it takes one face of the octagon to rotate into the position of the adjacent face. The advantage of this rotating mirror arrangement is that the angle of the octagon

can be measured much more accurately than the mean distance between the teeth of the rotating wheel. He got from these measurements the value 299,796 km. per second.

Not content with this experiment because of the possible disturbance of the air-path between the two mountains, he spent the last four years of his life preparing for and redetermining near Santa Ana, California, this velocity by means of multiple reflections between the ends of an underground pipe 1600 meters long, 30 cm. in diameter, from which the air had been pumped out to such an extent as to make it possible to measure directly for the first time the velocity essentially in vacuo. The final mean result, published after his death, may be taken as 299,774, which is one part in 2500 less than the best mean of his earlier measurements, another illustration of the fact that even the best of us tend to overestimate the precision of our work. The introduction to this last paper was written by Michelson but ten days before he lost consciousness. As he wrote it it had the same title as the paper with which he began his career, "On a Method of Measuring the Velocity of Light."

Going back, now, to the beginning of his career: By the measurement made in 1879 at Annapolis, Michelson had sprung at the age of twenty-six, and while he was still "Ensign Michelson of the U. S. Navy," into international repute as a physicist. That he received immediate popular acknowledgment is shown by the following interesting quotation from a local Virginia City paper published May 15, 1879, less than a year after his first published determination of the velocity of light:

"Ensign A. A. Michelson, a son of S. Michelson, the dry goods merchant of this city, has aroused the attention of the scientific minds of the country by his remarkable discoveries in measuring the velocity of light. The N. Y. Times in an article says that 'it would seem that the scientific world of America is destined to be adorned with a new and brilliant name.' Ensign A. A. Michelson, a graduate of Annapolis, not yet 27 years old, is distinguishing himself by studies in the science of optics in measuring the velocity of light."

But the importance of Michelson's work on the velocity of light is not to be measured alone by the absolute determinations thus far considered. He began his work in the period in which

physicists were trying to obtain crucial tests to distinguish definitely, if possible, between a wave theory and a corpuscular theory of light. Indeed, Foucault's method had been designed and used by him in 1862 primarily for the sake of finding by direct measurement whether the velocity in air was greater or less than the velocity in water, and he actually interposed a tube of water, closed at the ends by plane parallel glass plates, between his lens and his concave reflector and showed that the velocity is less in water than in air, as the wave theory demanded. In 1884, after Michelson had become (in 1883) Professor of Physics at Case School of Applied Science at Cleveland, he repeated this experiment of Foucault's and checked not only the latter's qualitative result, but he now made it definitely quantitative. He showed, also, that the ratio of the velocities in air and water is equal to the index of refraction, as demanded by the wave theory. He then performed the same experiment with carbon disulphide and here found the ratio of the velocities 1.75 instead of 1.64, as expected from the index of refraction. Confident, however, in the accuracy of his measurement, he published his results in spite of the apparent contradiction. Lord Rayleigh later removed the contradiction by showing that in a highly dispersive medium like carbon disulphide the *group velocity* is less than that computed from the mean index of refraction, and that the theory was quantitatively in accord with Michelson's measurements. Michelson also tested directly the velocities of red and blue light and found the former 2% greater than the latter,—a result of much importance at that time for the theory of dispersion.

IV. MICHELSON AND THE INTERFEROMETER

However important his work on the velocity of light may have been, the permanence of Michelson's place in physics undoubtedly rests in largest measure upon his invention of the Michelson interferometer and what he accomplished with it. Claude Bernard says that "a good technique sometimes renders more service to science than the elaboration of highly theoretical speculations," and George Hale has often remarked to me that

"after all the progress of physics is written in the history of the development of new instrumental techniques." Be this as it may, the history of the interferometer shows how vitally theory and experiment cooperate in the progress of science.

Early in 1879 Michelson left the Naval Academy, where he had been instructor in physics and chemistry since December 15, 1875, and was then employed for a year at the office of the Nautical Almanac in Washington. He and his wife and their two young children then started for Europe and he spent two years studying at Berlin, at Heidelberg, and at the College de France. At Paris he acquired a good command of French and became well acquainted with the French physicists of that period, particularly Mascart and Cornu, the latter of whom had made by Fizeau's toothed-wheel method a very excellent determination of the velocity of light, the value of which then stood at 299,990, while Michelson's value was at that time 299,940. It is probable that it was his careful study here in Paris of Fizeau's work that got him started on his main lifework in interferometry. For it was as early as 1851 that Fizeau had made his remarkable experiment on the effect of moving water on the speed of light passing through it. The method consisted in bringing into interference two rays of light after their passage through parallel tubes in which water was driven with a high speed, in one tube in the direction of travel of the light and in the other tube against that direction. It was but a step from this Fizeau form of interferometer to the one used by Michelson in which the two components of the split beam of light are sent off in directions at right angles to each other and brought back by mirrors placed at right angles to each beam, to the original separating surface for the observation of the fringes. The complete control of the path of each beam, however, and the possibility of varying each path at will, or of introducing in either path materials of any sort whose optical properties it might be desired to study, gave it an extraordinary flexibility as a tool for making exceedingly refined measurements. It is not too much to say that Michelson spent a large part of his active life and did his most important work in devising new uses for this tool and carrying out researches of all sorts with its aid. In a sense, the tool had been

here for decades before him, but why had not its possibilities been seen and utilized? Michelson once told me that when he first set up such a device in Paris and told Cornu how he got the fringes, Cornu was skeptical until he put a piece of cardboard in one of the right-angular paths and saw the fringes instantly disappear.

Michelson's first use of his interferometer was for testing the relative velocity of the earth and the ether. It was while he was still in Europe at the age of twenty-eight that he made his first try at this epoch-making experiment. He reports it in the American Journal of Science *22*, 120 to 129, 1881. He had tried it first in Berlin, then moved to the Astrophysikalisches Observatorium at Potsdam. In his brief report he thanks Alexander Graham Bell for supplying the funds for the investigation, and is so confident of the correctness of the negative result obtained that he asserts that "The hypothesis of a stationary ether is thus shown to be incorrect."

It is not until 1886 and 1887 that this experiment, repeated at Case School of Applied Science with great care and refinement by Michelson and Morley, begins to take its place as the most famous and in many ways the most fundamentally significant experiment since the discovery of electromagnetic induction by Faraday in 1831. The special theory of relativity may be looked upon as essentially a generalization from it.

Only second to it in importance is the use which Michelson made of his interferometer, especially in the years 1887 to 1897, in proving, through his penetrating and very skillful study of the so-called visibility curves characteristic of different spectral lines, the great complexity of all save a very few of such lines. It was the analysis of these visibility curves which brought the discovery that the so-called red cadmium line of wave-length 6,438.472 angströms (an angström is a ten-millionth of a millimeter) is so extraordinarily monochromatic that it is desirable to express the length of the international standard meter in terms of it. At the invitation of the International Bureau of Weights and Measures, Professor Michelson, with his collaborator, Professor Morley, spent the year 1892 carrying through this very exacting undertaking, with the result that the number

of the foregoing wave lengths in this standard was determined as 1,555,165.5.

Under this head should also come the extraordinarily fine work on the application of interferometry to the measurement of the diameters of stars done at the request of Dr. George E. Hale and in collaboration with F. G. Pease at the Mount Wilson Observatory between 1920 and 1925, a measurement which, for the first time made possible the direct determination of a stellar diameter, and, to take but one example, fixed the diameter of Betelgeuse at 240,000,000 miles,—about a hundred times that of the sun. The essentials of the method had been published by Michelson as early as 1890.

V. MICHELSON, SPECTROSCOPY AND GEOPHYSICS

No event in Michelson's career showed the originality of his mind better than the echelon spectroscope, which appeared in 1898. Unlike the interferometer, the accomplishment of this instrument has not been large because of its very narrow spectroscopic range; but the idea of obtaining high resolution by using this particular means of getting into a spectrum of very high order was at the time so novel that spectroscopists the world over were surprised and delighted with it. It showed, too, how fundamental an understanding its author had of all the elements of correct spectroscopic design. Its appearance probably had much to do with stimulating the minds of Fabry and Perrot to attain high spectroscopic resolution by modification of this route, which has found application to a somewhat larger number of problems.

The attainment of high spectroscopic resolution had by this time (1900) become a major objective with Michelson, and it was perhaps because he thought he had about exhausted the possibilities of the interferometer and the echelon for this purpose that he turned his attention to the problem that gave him more trouble and at the same time filled his associates with more admiration for him than any of its predecessors had done, namely, the problem of ruling very high resolution gratings. He had thought he could build a machine in a few months, or

at most a few years, which would give him the desired resolution, but he spent the rest of his life without reaching the point at which he was willing to drop the problem. He often said he regretted that he ever got "this bear by the tail," but he would not let go, and in spite of endless discouragements at the end of about eight years of struggle he had produced a good six-inch grating containing 110,000 lines (resolving power is measured by the number of lines times the order of the spectrum), which was 50% better than the best otherwise produced at that time and in 1915 he produced both an 8-inch and a 10-inch, which are still "among the most powerful instruments of diffraction that the world possesses," although with the extraordinary developments of quantum and nuclear physics the problem has become so important for physics, astronomy, chemistry, and even biology that a considerable number of institutions are now hard at the grating problem.

One of the finest things that Michelson ever said was inspired by his baffling experiences with his grating machines. It reads:

"One comes to regard the machine as having a personality—I had almost said a feminine personality—requiring humoring, coaxing, cajoling, even threatening. But finally one realizes that the personality is that of an alert and skillful player in an intricate but fascinating game, who will take immediate advantage of the mistakes of his opponent, who 'springs' the most disconcerting surprises, who never leaves any result to chance, but who nevertheless plays fair, in strict accordance with the rules he knows, and makes no allowance if you do not. When *you* learn them, and play accordingly, the game progresses as it should."

The problem of the rigidity of the earth which Michelson, in collaboration with Gale, solved so magnificently in 1919 is unlike most of Michelson's work in that it was undertaken at the request of others, particularly the geologist, T. C. Chamberlin, who was intensely interested in knowing how rigid the earth as a whole is. If it acted throughout like a fluid, then the land would move just as does water under the influence of the moon and the sun, and there would be no water tides at all relative to the surface of the earth. Could not Michelson suggest and carry out a method of making an exact measurement? Michelson at once devised the following exceedingly simple and direct

method which, however, save for the "fringe system" of measurement had been suggested earlier, I think by Airy, though never actually tried. It consisted in burying about ten feet under ground two six-inch iron pipes about 500 feet long, one running east and west, the other north and south, with an observation chamber at the junction point. The pipes were filled half full of water. The variation in the levels of the water at the ends of the pipes, as the moon and sun periodically produced their miniature tides in the water in these two pipes, were accurately measured by the movement they produced in a simple optical fringe system formed between the top of the water and a surface rigidly attached to the earth. The amplitude of the movement was from 6 to 11 microns. If the earth were not at all rigid, as already stated, there would be no relative movement of the earth and water in the pipes at all, and hence no movement of the fringes. If the earth were completely rigid the movement could be exactly computed from the pull of the moon and the sun. The movement was actually about half of that computed for an immobile earth.

These results, published in the Astrophysical Journal by Michelson and Gale for 1919, undoubtedly give the best values yet obtained of the earth's rigidity, as well as of its viscosity. The difficult tidal computations were carried out by F. R. Moulton of the University of Chicago, and his staff.

VI. MICHELSON, THE ARTIST

This sketch would not be complete without an endeavor to appraise somewhat more fully the artistic side of Michelson's personality. In a sense I have already paid the highest possible tribute to his artistry in describing the refinement and exactness of his measurements and the perfection of the design of his instruments, for are not discrimination in the choice of tools and methods and exact adaptation of means to end of the very essence of real art? Michelson was incessantly trying to perfect his artistic techniques, practicing his tennis strokes, taking lessons to improve his billiard shots. His students were continually commenting upon the perfection of the circles which in his lectures he drew with such ease on the blackboard. Is it at all

strange, then, that he was interested in music and a good performer on the violin? The connection between his accurate analysis of spectral colors and his love of painting landscapes and seascapes is a little less obvious, but be that as it may, in Southern California, where he spent a considerable fraction of the last ten years of his life, he divided his time between scientific pursuits and painting expeditions to the beaches, arroyos, and the High Sierras. In the summer of 1925, when I came down from a week spent studying cosmic rays in Muir Lake under the brow of Mt. Whitney, I found Michelson all alone seated with his easel in a favorable spot on the porch of the little Lone Pine Inn painting the glorious view he had found there of the snow-capped Whitney. In other words, he not only had the skill of the artist but also the feelings of the artist. He wrote two papers in which he gave expression to these feelings; one written in 1906 is entitled "Form Analysis." In it he attempts a classification of symmetrical forms as they are found in nature, and expresses the delight he found in these discoveries. He made this analysis, however, rather as a recreation than as a serious study. The other paper, written in 1911, is on "The Metallic Coloring of Birds and Insects," and in it, while he has set himself the scientific objective of finding whether the irridescent colors found in birds and insects are due to pigmentation, interference, or metallic reflection, he gives expression to the feelings aroused in him by these beautiful color effects found in nature. Also in a paragraph from the Lowell Lectures he uses the following words:

"The aesthetic side of the subject is by no means the least attractive to me. I hope the day is near when a Ruskin will be found equal to the description of the beauties of coloring, the exquisite gradations of light and shade, and the intricate wonders of symmetrical forms and combinations which are encountered everywhere."

In 1928, a few years before Professor Michelson's death, a conference on the Michelson-Morley experiment was held at Pasadena. It was a distinguished gathering, with both Lorentz and Michelson having a part in the program. The latter was scheduled to make a final report on the repetition he had just

made on Mt. Wilson of this famous experiment. Roy Kennedy, a young physicist who had repeated this experiment at the Norman Bridge Laboratory in a new way and with much precision, preceded Michelson. With a generosity and courtesy altogether characteristic of him, Michelson rose and complimenting Kennedy enthusiastically upon the beauty and precision of his experiment said, "Your work, Dr. Kennedy, renders my own work quite superfluous. I should not have undertaken it had I known you were doing it so well." It was one of the finest tributes Michelson could have paid *to himself*.—A wonderful ending of a wonderful career, for this was Michelson's last public appearance.

The bibliography of his published papers, as prepared by Professors Monk and Lemon of the Ryerson Laboratory, is given below.

MICHELSON IN HIS SEVENTIES

BIBLIOGRAPHY OF PUBLICATIONS OF ALBERT ABRAHAM MICHELSON*

Books

Détermination expérimentale de la valeur du mètre en longueurs d'ondes lumineuses, mémoire traduit de l'anglais par M. J. René Benoît (Gauthier-Villars, 1894).

Light Waves and Their Uses (Univ. Chicago Press, 1903).

Lichtwellen und ihre Anwendungen, übers und durch zusätze erweitert von Max Iklé (Barth, 1911).

Studies in Optics (Univ. Chicago Press, 1927).

***Light Waves and Their Application,* Russian tr. (Mathesis, Odessa, 1912). Another translation was published in St. Petersburg in 1912.

Articles

Papers listed under the same number are identical except when distinguished by a sub-classification, in which case the nature of the differences is explained.

(*a*) "On a Method of Measuring the Velocity of Light," Am. J. Sci. (3) **15**, 394-95 (1878); (*b*) "Velocity of Light (Preliminary Announcement)," Nature **18**, 195 (1878), differs from (*a*) in the addition of a paragraph.

"Experimental Determination of the Velocity of Light," Proc. A. A. A. S. **27**, 71-7 (1878).

"Experimental Determination of the Velocity of Light": (*a*) Proc. A. A. A. S. **28**, 124-60 (1879); (*b*) Nature **21**, 94-6, 120-22, 226 (1879-80), gives corrected values of velocities; (*c*) Am. J. Sci. (3) **18**, 390-93 (1879), abstract.

"Experimental Determination of the Velocity of Light," U. S. Naut. Almanac Office, Astron. Papers **1**, Part III, 115-45 (1880).

"Modifications Suffered by Light in Passing Through a Very Narrow Slit," Phil. Soc. Wash., Bull. III, 119-20 (1878-80). An abstract, not made by Michelson, of a paper read by him before the Society; its substance is not included elsewhere in this bibliography.

"The Relative Motion of the Earth and the Luminiferous Ether," (*a*) Am. J. Sci. (3) **22**, 120-29 (1881); (*b*) Comptes rendus **94**, 520-23 (1882), a shortened account of (*a*) with a correction.

"Nouveau thermomètre très sensible, J. de Physique (2) **1**, 183-86 (1882); Séances de la Soc. de Physique, Paris, 66-9 (1882-83).

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* Acknowledgments are due to Ardis T. Monk for the accurate revision of this bibliography from one previously published in J. O. S. A. **18**, 151 (1929).

** These items are not verified.

"Interference Phenomena in a New Form of Refractometer," Phil. Mag. (5) **13**, 236-42 (1882); Am. J. Sci. (3) **23**, 395-400 (1882).

"An Air-thermometer Whose Indications Are Independent of the Barometric Pressure," Am. J. Sci. (3) **24**, 92 (1882).

"A Method for Determining the Rate of Tuningforks," Phil. Mag. (5) **15**, 84-7 (1883); Am. J. Sci. (3) **25**, 61-4 (1883).

"On the Velocity of Light in Carbon Disulphide and the Difference in Velocity of Red and Blue Light in the Same," Report, British A. A. S., 654 (1884).

"Supplementary Measures of the Velocities of White and Colored Light in Air, Water, and Carbon Disulphide," U. S. Naut. Almanac Office, Astron. Papers **2** (1891), Part IV, 231-58 (1885).

"Influence of Motion of the Medium on the Velocity of Light" (with E. W. Morley), Am. J. Sci. (3) **31**, 377-86 (1886).

"On the Relative Motion of the Earth and the Luminiferous Ether" (with E. W. Morley): (*a*) Am. J. Sci. (3) **34**, 333-45 (1887); Phil. Mag. (5) **24**, 449-63 (1887); (*b*) Sidereal Messenger **6**, 306-10 (1887), abstract of (*a*).

"On a Method of Making the Wave-length of Sodium Light the Actual and Practical Standard of Length" (with E. W. Morley), Am. J. Sci. (3) **34**, 427-30 (1887); Phil. Mag. (5) **24**, 463-66 (1887).

"A Plea for Light Waves," address before physics section, Proc. A. A. A. S. **37**, 3-14 (1888).

"On the Feasibility of Establishing a Light-wave as the Ultimate Standard of Length" (with E. W. Morley), Am. J. Sci. (3) **38**, 181-86 (1889).

"Measurement by Light-waves," (*a*) Am. J. Sci. (3) **39**, 115-21 (1890); (*b*) "Note on the Definition, the Resolving Power and the Accuracy of Telescopes and Microscopes," Publ. A. S. P. **2**, 115-17 (1890), reprint of (*a*) with a small correction.

"A Simple Interference Experiment," Am. J. Sci. (3) **39**, 216-18 (1890).

"On the Application of Interference Methods to Astronomical Measurements," Phil. Mag. (5) **30**, 1-21 (1890); Memoirs, Nat. Acad. Sci. **5**, 579-90 (1891).

"Measurement of Jupiter's Satellites by Interference," Publ. A. S. P. **3**, 274-78 (1891); Nature **45**, 160-61 (1892).

"Visibility of Interference-Fringes in the Focus of a Telescope," Phil. Mag. (5) **31**, 256-59 (1891); Publ. A. S. P. **3**, 217-20 (1891).

"On the Application of Interference-Methods to Spectroscopic Measurements. I," Phil. Mag. (5) **21**, 338-46 (1891).

"On the Application of Interference-Methods to Spectroscopic Measurements. II," Phil. Mag. (5) **34**, 280-99 (1892); Smithsonian Contributions to Knowledge, 842 (1892); Report, British A. A. S. 170-71 (1892).

"Comparison of the International Meter with the Wave-length of the Light of Cadmium," Astron. and Astrophys. **12**, 556-60 (1893); Comptes rendus **116**, 790-94 (1893).

"Les Méthodes interférentielles en métrologie et l'établissement d'une longueur d'onde comme unité absolue de longueur," (*a*) J. de Physique (3) **3**, 5-22 (1894); Séances de la Soc. de Physique, Paris, 159-72 (1893); (*b*) Revue générale des sciences **4**, 369-77 (1893), some changes in figures.

"Light Waves and Their Applications to Metrology," Astron. and Astrophys. **13**, 92-104 (1894); Nature **49**, 56-60 (1893-94).

"On the Conditions Which Affect the Spectro-Photography of the Sun," Astrophys. J. **1**, 1-9 (1895).

"On the Limit of Visibility of Fine Lines in a Telescope," Astrophys. J. **2**, 60-2 (1895).

"On the Broadening of Spectral Lines," Astrophys. J. **2**, 251-63 (1895).

"A Theory of the 'X-Rays'," Am. J. Sci. (4) **1**, 312-14 (1896).

"Source of X-Rays" (with S. W. Stratton), Science, N. S. **3**, 694-96 (1896).

"On the Relative Motion of the Earth and the Ether," Am. J. Sci. (4) **3**, 475-78 (1897).

"Radiation in a Magnetic Field," Astrophys. J. **6**, 48-54 (1897); Phil. Mag. (5) **44**, 109-15 (1897).

"Radiation in a Magnetic Field," Astrophys. J. **7**, 131-38 (1898); Phil. Mag. (5) **45**, 348-56 (1898).

"Radiation in a Magnetic Field," Nature **59**, 440-41 (1898-99), reply to a paper by T. Preston, Nature **59**, 224-29 (1898-99).

"A Spectroscope Without Prisms or Gratings," Am. J. Sci. (4) **5**, 215-17 (1898), preliminary notice to next paper.

"The Echelon Spectroscope," Astrophys. J. **8**, 37-47 (1898).

"The Echelon Spectroscope": (*a*) Proc. Am. Acad. Arts and Sci. **35**, 111-19 (1899-1900); Cambridge Phil. Trans. **18**, 316-23 (1899); (*b*) J. de Physique **8**, 305-14 (1899), has an additional paragraph and differences in the figures.

"A New Harmonic Analyzer" (with S. W. Stratton), Am. J. Sci (4) **5**, 1-13 (1898); Phil. Mag. (5) **45**, 85-91 (1898).

"Fourier's Series": (*a*) Nature **58**, 544-45 (1898); (*b*) Nature **59**, 200 (1898-99). Two short letters, not identical.

"Nouvelle méthode de tracer et d'observer des divisions de précision, formées par des traits lumineux sur fond noir," proces-verbaux des séances de Comité International des Poids et Mesures, 181-84 (1899).

"The Velocity of Light," Univ. of Chicago Decennial Publ. (1) **9**, 3-9 (1902); Phil. Mag. (6) **3**, 330-37 (1902).

"On the Spectra of Imperfect Gratings," Astrophys. J. **18**, 278-86 (1903).

"Relative Motion of Earth and Ether," Phil. Mag. (6) **8**, 716-19 (1904).

** "Comparaison du microscope et du téléscope avec l'interféromètre traduit de l'anglais, Věst. opytn. fiziki, Odessa **22**, 128-38, 153-61 (1904).

** "L'ether," traduit de l'anglais, Fiz. Obozr., Varsava (5) **4**, 158-71 (1904).

** These items are not verified.

"Report of Progress in Ruling Diffraction Gratings," Phys. Rev. [1] **20**, 389 (1905).

"Reciprocal Diffraction Phenomena," Phys. Rev. [1] **20**, 391 (1905).

"Use of the Concave Mirror with Diffraction Gratings," Phys. Rev. [1] **20**, 391 (1905).

"A Reciprocal Relation in Diffraction," Phil. Mag. (6) **9**, 506-7 (1905).

"Form Analysis," Proc. Am. Phil. Soc. **45**, 110-16 (1906).

"Recent Advances in Spectroscopy," Nobel Address, Roy. Acad. Sci., Stockholm (1907).

"Recent Progress in Spectroscopic Methods," Science **34**, 893-902 (1911); Naturwissenschaftliche Rundschau **27**, 221-23, 237-40 (1912).

"On Metallic Colouring in Birds and Insects," Phil. Mag. (6) **21**, 554-67 (1911); reprinted in *Studies in Optics*.

"Effect of Reflection from a Moving Mirror on the Velocity of Light," Astrophys. J. **37**, 190-93 (1913).

"Determination of Periodicities by the Harmonic Analyzer with an Application to the Sun-Spot Cycle," Astrophys. J. **38**, 268-74 (1913).

"The Ruling and Performance of a Ten-Inch Diffraction Grating," Proc. Am. Phil. Soc. **54**, 137-42 (1915); Proc. Nat. Acad. Sci. **1**, 396-400 (1915); J. Franklin Inst. **181**, 785-89 (1916); Carnegie Inst. Wash. Yearbook **14**, 402 (1915).

"Preliminary Results of Measurements of the Rigidity of the Earth," Astrophys. J. **39**, 105-38 (1914); J. Geol. **22**, 97-130 (1914).

"The Laws of Elastico-Viscous Flow," (*a*) Proc. Nat. Acad. Sci. **3**, 319-23 (1917); (b) J. Geol. **25**, 405-10 (1917), practically identical with (*a*).

"On the Correction of Optical Surfaces," (*a*) Astrophys. J. **47**, 283-88 (1918); (*b*) Proc. Nat. Acad. Sci. **4**, 210-12 (1918), shortened version of (*a*).

"The Rigidity of the Earth" (with H. G. Gale): (*a*) Astrophys. J. **50**, 330-45 (1919); J. Geol. **27**, 585-601 (1919); (*b*) Science **50**, 327 (1919); Nature **104**, 114 (1919). Papers (*b*) contain identical corrections.

"Optical Conditions Accompanying the Striae which Appear as Imperfections in Optical Glass," U. S. Bur. Standards, Sci. Papers, No. 333 **15**, 41-5 (1919-20).

"On the Application of Interference Methods to Astronomical Measurements": (*a*) Astrophys. J. **51**, 257-62 (1920); Mt. Wilson Contr., No. 184; Comptes rendus **171**, 15-9 (1920); (*b*) Proc. Nat. Acad. Sci. **6**, 474-75 (1920), brief version of (*a*).

"The Laws of Elastico-Viscous Flow. II," Proc. Nat. Acad. Sci. **6**, 122-27 (1920); J. Geol. **28**, 18-24 (1920).

"The Vertical Interferometer," Proc. Nat. Acad. Sci. **6**, 473-74 (1920).

"A Modification of the Revolving Mirror Method for Measuring the Velocity of Light," Proc. Nat. Acad. Sci. **6**, 476-77 (1920).

Measurement of the Diameter of Alpha Orionis with the Interferometer" (with F. G. Pease), (*a*) Astrophys. J. **53**, 249-59 (1921); Mt. Wilson Contr., No. 203; (*b*) Proc. Nat. Acad. Sci. **7**, 143-46 (1921), brief version of (*a*).

"Some Recent Applications of Interference Methods," Proc. Phys. Soc. London **33**, part IV, 275 (1921), Sixth Guthrie Lecture.

"Preliminary Experiments on the Velocity of Light," Astrophys. J. **60**, 256-61 (1924).

"Preliminary Measurement of the Velocity of Light," J. Franklin Inst. **198**, 627-28 (1924); "New Measurement of the Velocity of Light," Nature **114**, 831 (1924). Abstract of preceding paper.

"On the Limit of Accuracy in Optical Measurement," J. O. S. A. **8**, 321-28 (1924).

"On the Effect of Small Particles in the Vitreous Humor," J. O. S. A. **9**, 197-200 (1924).

"The Effect of the Earth's Rotation on the Velocity of Light" (with H. G. Gale), Astrophys. J. **61**, 137-45 (1925).

"Light-Waves as Measuring Rods for Sounding the Infinite and the Infinitesimal," Univ. Chicago Rec., N.S. **11**, 136-53 (1925).

"Measurement of the Velocity of Light between Mount Wilson and Mount San Antonio" (with Appendix III by Wm. Bowie), Astrophys. J. **65**, 1-14, 14-22 (1927); Mt. Wilson Contr., No. 329.

"Conference on the Michelson-Morley Experiment," Astrophys. J. **68**, 341-402 (1928), reports by Michelson, Lorentz, Miller, Kennedy, Hedrick, Epstein.

"Measurement of the Velocity of Light in a Partial Vacuum" (with F. G. Pease and F. Pearson), Astrophys. J. **82**, 26-61 (1935).

N. L. Britton

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OF

NATHANIEL LORD BRITTON

1859–1934

BY

E. D. MERRILL
With bibliography by
JOHN HENDLEY BARNHART

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1938

NATHANIEL LORD BRITTON

1859–1934

BY E. D. MERRILL

To establish one's self as one of the outstanding productive botanists of his time is an achievement in itself, but it is quite another thing at the same time to develop in connection with one's active scientific work, an outstanding scientific institution planned to perpetuate and increase research in the field in which the individual was interested. Yet this is the record of accomplishment of the subject of this biographical memoir. As ably expressed by Doctor Marshall A. Howe:

"Opportunity and the man conjoined to make the career of Nathaniel Lord Britton a notable one. The City of New York, spacious and wealthy, was a fitting site for an institution to be devoted to the study of plant sciences and to the public display of plants and plant products of scientific, economic, and horticultural interest. Doctor Britton was the man of vision, energy, and resource, who, above all others, made the dream of a few a living reality. In a very large measure, it was his driving, vitalizing force that, within less than thirty-five years, converted raw materials into the New York Botanical Garden, one of the leading institutions of the kind in the world."

Born at New Dorp, Staten Island, now the Borough of Richmond of New York City, on January 15, 1859, Doctor Britton died at his home, 2965 Decatur Avenue, New York, June 25, 1934, in the seventy-sixth year of his age. He was the son of [Jasper] Alexander Hamilton Britton and Harriet Lord Turner, and it has been said that his parents hoped that he might follow a clerical career. The interest of a neighbor, John J. Crooke, an individual of considerable scientific attainments himself, led to young Britton's being sent to the School of Mines in Columbia College, where he was prepared for his future scientific career. Doubtless his early close association with the late Doctor Arthur Hollick, a classmate in the School of Mines, and the influence of Professor John Strong Newberry, Professor of Geology and Mineralogy, and an "old school" naturalist, had their effect on the shaping of Doctor Britton's future career.

It is probable that Doctor Britton was a descendant of James Britton who came to the American colonies from London in 1635, although it seems likely that the name was of French rather than of English origin. The name is not an uncommon one in the early records of New Jersey and New York. In any case William Britton settled on Staten Island about 1664. In 1695 Nathaniel Britton acquired title to the Obadiah Holmes property in New Dorp, Staten Island, and in 1925 Nathaniel Lord Britton and his wife Elizabeth Gertrude, deeded a part of this land, with the old Britton cottage, to the Staten Island Institute of Arts and Sciences to ensure its preservation as long as possible as an example of early colonial construction.

It is apparent that Doctor Britton's interest in botany developed at an early age, long before he entered college, for it is recorded that even as a child he knew the names of local plants in a way that seemed very mysterious to his parents. In any case, in spite of his collegiate training in geology and mining, the study of plants soon became his dominant interest.

In 1879, before he had reached his twenty-first birthday, he was graduated from the School of Mines of Columbia College with the degree of Engineer of Mines. At that time there was little formal instruction in botany in Columbia College, Professor Newberry giving lectures in both geology and botany. He had published numerous papers on fossil plants and a few on living ones, and naturally encouraged young Britton's botanical interests. Like many others who made their mark in botanical science in the days before the great development of laboratory technique so characteristic of modern botanical training, Dr. Britton's interest was a personal one because of his abiding interest in plants and in plant life. He was to a very considerable degree self-trained in his chosen career. He joined the Torrey Botanical Club in October, 1877, and in the year of his graduation his first extensive botanical paper appeared, this being "The flora of Richmond County, New York," in joint authorship with Arthur Hollick, although he had published shorter botanical notes in 1877 and 1878.

Following his graduation from the School of Mines he was appointed Assistant in Geology under Professor Newberry and

for the five succeeding years he also served as Botanist and Assistant Geologist on the Geological Survey of New Jersey. In 1881 his "Preliminary Catalogue of the Flora of New Jersey" appeared, this apparently serving as his thesis for the degree of Doctor of Philosophy which he received that year from Columbia College. In 1887 he received an appointment as Instructor in Botany and Geology, at Columbia. He even gave courses in zoology in 1887-88. At this time he largely took over Professor Newberry's botanical instruction. In 1890 he was appointed Adjunct Professor of Botany, and in 1891 Professor of Botany. On his appointment as Director-in-Chief of the newly established but as yet unorganized New York Botanical Garden in 1896 he became Professor of Botany Emeritus at the early age of thirty-seven years. Under arrangements perfected between the Garden and Columbia University, the Director of the Garden became, ex-officio, a Professor of Botany in the University.

Doctor Britton was married on August 27, 1885 to Elizabeth Gertrude Knight who materially assisted him in his botanical efforts because of her own abiding interest in botany. Starting with a keen interest in the local flora he gradually extended his field assembling data, perhaps unconsciously at first, but later with the definite motive of preparing the famous Britton and Brown "Illustrated Flora of the Northern United States and Canada" which appeared in three volumes 1896-98; there was a second edition in 1913, and this, forty years after its first publication, is still standard although, of course, revision is now needed. It was the first fully illustrated "Flora" on any part of North America. The preparation of such a work, an enormous task in itself, did not restrict the author's output of other papers, and during much of the period devoted to its preparation Doctor Britton served as editor of the Bulletin of the Torrey Botanical Club (1889-97), the pioneer American botanical periodical.

The illustrated flora project was the joint idea of Doctor Britton and Judge Addison Brown. Its preparation was made possible through funds provided by Judge Brown, but there is every reason to believe that the initial outlay was repaid by royalties from its sale. This reference work, although of course

more or less out of date, is still in demand, with steady annual sales of several hundred copies each year. While Doctor Britton devoted an enormous amount of time to its preparation, Judge Brown worked with him throughout the period of its preparation and publication.

Other outstanding major works include his "Manual of the Flora of the Northern States and Canada" (1901, ed. 2, 1905, ed. 3, 1907), "North American Trees" (1908, with J. A. Shafer), the "Flora of Bermuda" (1918), the "Bahama Flora" (1920, with C. F. Millspaugh), and "The Botany of Porto Rico and the Virgin Islands" (1923-30, with P. Wilson). His *magnum opus,* prepared in association with J. N. Rose, is "The Cactaceae", a four volume, copiously illustrated monograph of this most difficult plant family, published by the Carnegie Institution of Washington, 1919-23. In this work 124 genera and about 1,237 species of this perplexing family are described. No matter what future botanists may attempt or achieve in their consideration of this great family of plants, this Britton and Rose monograph forms a datum plane from which all future work must proceed.

Doctor Britton became interested in the flora of the West Indies at an early date, the first expedition being sent by the Garden in 1898, his own first field trip being in 1901. He participated personally in at least thirty botanical expeditions in the islands, for he was convinced that exploration of this region would be most fruitful. Most of this West Indian work was financed by him personally. In connection with the problem of financing field work he was most successful in developing cooperative expeditions whereby several institutions contributed to the expenses of field parties, the resulting collections being equitably divided among the cooperating units.

Throughout his productive life, Doctor Britton was a voluminous writer. In his earlier career, teaching duties, while of course taking time, were not allowed to restrict his productive activity, for it should be remembered that it was Britton who established and organized the Department of Botany in Columbia University. When he took charge he found very inadequate literary facilities, comprising not more than 1000 volumes. The

valuable herbarium established by Doctor John Torrey, rich in types and historical material, was in the greatest disorder, suffering from neglect, and in utterly inadequate quarters. He undertook, with the greatest zeal and energy, the task of correlating the scattered elements into one series of botanical specimens and the building up of a botanical library worthy of the University. Within a few years the herbarium was more than tripled in size and the botanical library was vastly increased. Later, when charged with very heavy organization and administrative duties at the New York Botanical Garden, we find the same situation to prevail; nothing was permitted unduly to interfere with his productive output in botany. One marvels at his energy, his ceaseless mental activity, and at the diverse productive results.

In view of the comprehensive bibliography appended to this paper there is little need to go into detail regarding Doctor Britton's publishing activities. The long list speaks for itself. Others unhampered by exacting demands on their time by social duties, political contacts, appeals for funds, dealings with architects, engineers, city and corporation officials, and a thousand and one details appertaining to the establishment, financing, and development of a great institution may look with equanimity on their productive output in publication. Yet one wonders how many of them could have continued to be productive had they been faced with the multitudinal problems, large and small, that Doctor Britton met day after day, week after week, month after month, year in and year out, and still find time to produce technical paper after technical paper. It takes a rare combination of qualities, and above all persistence, abiding faith in one's work, and deep and unfaltering interest in the daily task to produce results under such circumstances, and these qualities were Doctor Britton's to an eminent degree. He worked unceasingly himself and he expected his associates to do likewise. Above all he provided the opportunities for his associates to accomplish that in which they were individually interested through his organizing and administrative ability.

After all is said and done, in spite of Doctor Britton's notable contributions to botanical science, his greatest achievement was

undoubtedly the establishment and development of the New York Botanical Garden, a living monument to his memory. The institution was his in a very real sense, and to it he devoted his best efforts through much of his productive life.

Doctor Britton himself is the authority for the statement that the idea of establishing such an institution was due to a remark made by Mrs. Britton in 1888, when they were visiting the Royal Botanic Gardens at Kew, to the effect "Why couldn't we have something like this in New York?" On October 24, 1888, Mrs. Britton gave a description of Kew at a meeting of the Torrey Botanical Club, and at the next meeting of the Club a special committee was appointed, of which Doctor Britton was a member, to consider what might be done in reference to the establishment of a botanical garden in New York. On January 8, 1889, an appeal for such a garden, prepared by the committee, was adopted and ordered printed. How many potentially great projects stop here. The situation has been ably presented by Doctor H. H. Rusby.*

"Doctor Britton's accomplishment in the establishment of our Botanical Garden is not likely to fail of appreciation by future generations, but they might easily fail to appreciate the difficulties attending such a vast work on such insufficient resources. Looking back on the conditions that confronted the enterprise, they seem appalling, and the undertaking hopeless—yet—here is the garden, just pride of a nation! None of the enthusiastic botanical band, with the exception of Judge Brown, possessed enough means to justify even the starting of a subscription list, and but a very few of them had wealthy associates who might become interested. Again it was Doctor Britton who succeeded in inducing those few to initiate a campaign for funds. For years, the attempt persisted, but the work lagged and it was not until a determined group of women, led by Mrs. Britton, took to the warpath, that the minimum endowment of $250,000 was secured, and of this only the income might be used. Money for grading, road, path and bridge building, the location of lakes and the erection of buildings and conservatories, had still to be secured from the city administration."

Following the adoption of the committee report by the Torrey Botanical Club January 8, 1889, the consent of the Department

* Science n. s. 80: 108-111. 1934.

of Parks was secured providing for the establishment of the proposed garden could means for its maintenance be procured. The corporation known as "The New York Botanical Garden" was chartered by special enactment of the New York Legislature effective April 28, 1891. The list of incorporators included the names of forty-eight distinguished citizens of New York. The Act authorized and directed the Park Commissioners to set aside for the proposed garden an area not exceeding 250 acres in some park north of the Harlem River, if, within seven years, the corporation should procure by subscription an initial endowment of not less than $250,000.

About four years later, when the required amount had been subscribed, the Park Commission was requested to set aside 250 acres in Bronx Park as a garden site, and the Board of Estimate was requested to appropriate $500,000 for the erection of suitable buildings, as had been made mandatory by the Act of the state legislature. The officers of the first Board of Managers consisted of Cornelius Vanderbilt, President; Andrew Carnegie, Vice-president; J. Pierpont Morgan, Treasurer; and N. L. Britton, Secretary.

In New York City there are several quasi-city units of great cultural value to the community. They are in part supported by direct city appropriations, in part by income from their endowments, and by gifts from philanthropically minded citizens; all are under the control of their own governing boards. Already established and in operation on this principle were the Metropolitan Museum of Art, the American Museum of Natural History, the New York Public Library, and the Brooklyn Institute of Arts and Sciences. To this category was now added the New York Botanical Garden, another orphan, adopted by and in part supported by the City; and soon after this (in 1895) the New York Zoological Park.

Late in 1895 or early in 1896 an agreement was made with Columbia College whereby the herbarium and botanical library of that institution were to be deposited at the Garden, the facilities of the Garden to be made available to the faculty and advanced students of Columbia College. On June 17, 1896, Doctor Britton was formally appointed Director-in-Chief of the new

institution. The garden site, 250 acres, in Bronx Park had been set aside in July 1895, to be increased in 1915 to an area of nearly 400 acres.

The challenge that Doctor Britton met was 250 acres of raw undeveloped land, no roads, bridges, fences, or buildings, an assured endowment of $250,000 of which the income only could be used, no laboratories, library, or herbarium, no staff, but with the hope of some financial support from the city and the potential hope that citizens of means would by gift or bequest, help support the infant institution. How well he met the challenge may be briefly indicated by the statement that in the thirty-three years of his directorate he saw the Garden develop from an idea to a well developed tract of 400 acres, a commodious administrative building and museum, ample greenhouse and conservatory facilities, a great collection of books containing 43,500 bound volumes, one of the great botanical libraries of the world, a reference herbarium in excess of 1,700,000 specimens from all parts of the world, well equipped laboratories, an active and productive staff, a publishing institution sending its product to the ends of the world, its initial endowment of $250,000 increased to approximately $2,500,000, an auxiliary membership (annual, supporting, and life) of nearly 2000 individuals, and its annual city appropriation greatly increased. The end attained justified the faith of the moving spirit in the enterprise, but how many men, situated as Doctor Britton was in 1895, would have had the courage to accept the challenge, and had the faith that the desired end could be accomplished?

One marvels at the early and rapid expansion of this new institution, particularly when one considers the paucity of financial support in the early critical years. As expressed by Doctor Rusby, who also quotes the expression that in those early years every dollar of the Garden's funds was made to do the work of four: "This success, in carrying the garden through its lean early decades, could never have been accomplished but for the generous and self-denying support of as loyal a staff as has ever blessed any similar institution, and this devotion was in no small degree attributable to the director's personality." Explorations were initiated in various parts of North America, in the Philip-

pines, in the West Indies, and in South America. A well-rounded research program, not confined to the taxonomy of the flowering plants and cellular cryptogams was rapidly developed, including plant physiology, plant pathology, palaeobotany, and popular education. Manuals were prepared covering the floras of the northeastern United States, the southeastern States, and the Rocky Mountain region. Soon there appeared in the periodical field the "Journal" and the "Bulletin" of the New York Botanical Garden, a series of "Contributions," and the "Memoirs," somewhat later to be followed by the establishment of "Mycologia" and "Addisonia." As early as 1901 work on the preparation of the "North American Flora" was initiated, originally planned to be completed in thirty volumes. Intended as a descriptive flora to cover all known North American species of plants in all groups from Alaska and Greenland to the West Indies and Panama, seventy-four parts were published in Doctor Britton's lifetime. This extensive undertaking was due in large part to Doctor Britton's initiative, the work being done by members of the staff of the New York Botanical Garden, with important contributions from botanists in other institutions. As another indication of his keen insight into what is necessary in a publishing botanical institution he pioneered again in creating the position of bibliographer on the staff, the first position of the kind, it is believed, in any botanical institution.

Doctor Britton's personal interests in the development of the work of the Botanical Garden were particularly strong in the building up of the very comprehensive botanical library and the great reference herbarium. He did not limit the accessions to publications and material appertaining particularly to the problems or to the areas in which he was personally interested. He took an exceedingly catholic viewpoint, in his desire to make the conditions as to material and literature of equal value to all staff members regardless of their fields of special interest. To the library he presented all published material that was personally sent to him by correspondents from all over the world, and freely used his own personal funds and secured funds from various other sources to acquire important sets of plants and private

herbaria as they became available to enrich the reference collections, and books to enrich the library.

His breadth of view is illustrated by the plan originated and consummated by him of bringing together in one place the scattered herbaria and botanical literature in New York, at the Garden, including the historical Torrey herbarium and the general herbarium of Columbia University, that of Barnard College, and the herbarium of the American Museum of Natural History. His interest was not limited to the higher plants as witnessed by his fortunately consummated plans of acquiring for the Garden the very important Ellis and Everhart collection of fungi, and the magnificent Mitten collection of mosses, both collections being exceedingly rich in historical material and containing many thousands of types. In the library field he planned and consummated the purchase of all the botanical works in the library of the Conservatoire et Jardin botaniques de Genève that were duplicated when the very important DeCandolle library was presented to the latter institution, thus vastly increasing the library resources of the New York Botanical Garden.

Outside of the library and herbarium interests of Doctor Britton was the field of palaeobotany. He took advantage of the opportunity of broadening the field of the New York Botanical Garden by establishing palaeobotanical work at the Garden, fully realizing, as apparently others have not done, that palaeobotanical research can best be done in close association with a great reference herbarium. In developing this field he naturally turned to his early associate Doctor Arthur Hollick, giving him the opportunity of developing this special field of investigation at the Botanical Garden. In no other botanical institution in America, and in very few elsewhere, was the field of research so broadly planned and developed as under Doctor Britton's leadership at this, the youngest and yet one of the greatest, botanical gardens in the world.

Doctor Britton was naturally the recipient of many honors, but honors rested lightly on his shoulders. He was the recipient of the Sc.D. degree from Columbia University in 1904, and the LL.D. degree from the University of Pittsburgh in 1912. He was elected a Fellow of the American Academy of Arts and

Sciences in 1925, a member of the National Academy of Sciences in 1914, a member of the American Philosophical Society in 1928, and a foreign member of the Linnean Society of London in 1925. He served as Vice President of the American Association for the Advancement of Science in 1896, President of the Botanical Society of America in 1898 and in 1920, President of the New York Academy of Science in 1907, and was made honorary president of the International Desert Conservation League in 1930. He was chairman of the Scientific Survey of Porto Rico and the Virgin Islands from its organization, at his instigation, by the New York Academy of Sciences, until his death. In the latter part of 1934, a peak 3200 feet high in the Luquello National Park in Porto Rico was named Mount Britton in his honor, in appreciation of his many years of service in developing our biological and geological knowledge of Porto Rico.

Although slight in build and of frail physique, Doctor Britton was a man of tireless energy, quick to perceive and to execute what needed to be done, with a remarkably retentive memory, a highly developed faculty for order and dispatch, and with the gift of concise expression. He was an individual of pronounced ideas, and in the often acrid nomenclatural controversies of the last decade of the last century and the first decades of the present one, he was an outstanding champion of strict priority in publication and a strong exponent of the so-called "American" code of botanical nomenclature as contrasted to the international rules. As a result his own publications and most of those prepared by his associates in New York were issued under the "American" code. Many botanists frankly admit that certain provisions of the "American" code were superior to the original provisions of the International code. The two are now so measurably close, except on the two questions of conserved generic names and Latin diagnoses, that the acrid controversies of the productive years of Doctor Britton's botanical career are now but a memory. Differences of opinion could not be avoided between exponents of the conservative viewpoint in nomenclature and the progressive or liberal element, and Dr. Britton was a consistent liberal.

While Doctor Britton would be considered conservative in the

matter of delimiting species, in generic segregation he was extreme, rather than conservative, tending to separate genera on what many botanists consider to be slight characters. Essentially, genera and species being subjective concepts, rather than objective realities, no such thing as legislative authority, as to what shall constitute the limits of a genus or a species, is possible. Doctor Britton did not dictate to his associates and subordinates, but rather let each use his own judgment on the complex problem of what constitutes the limits of this or that major or minor group. Always an individual of strong convictions, never hesitating to express his own ideas, no matter whether others might be expected to agree with him or not, Doctor Britton continued his productive work regardless of some perhaps just, but some distinctly unjust criticism. He knew what he desired to accomplish and was eminently successful in devising ways and means of accomplishing his purpose. His great accomplishment in the establishment of the New York Botanical Garden in a great and essentially commercial city, was never more than a means to an end with him, for always first and foremost in his thoughts was botanical research, the means for making such research possible, and the publication of the results obtained.

As his own financial resources increased he liberally supported, by his own personal funds, those projects that appealed to him, particularly those associated with the New York Botanical Garden. On his death, indicating his abiding faith in the institutions he helped to organize and to develop through their years of struggle, he bequeathed one-half of his estate in varying amounts, to the New York Botanical Garden, the Torrey Botanical Club, the New York Academy of Sciences, the Staten Island Institute of Arts and Sciences, and Columbia University.

Doctor Britton's wife, Elizabeth Gertrude Britton, herself a botanist of note, died four months before him, and from this shock of separation Doctor Britton never fully recovered. There were no children. He was survived by a sister, Harriet Louise Britton, and a brother, Richard H. Britton, both of Great Kills, Staten Island.

Sixty-nine species and varieties of living and fossil plants have been dedicated to Doctor Britton, and fifteen plants and

one animal have been named for Mrs. Britton. In addition two species of plants have been named in honor of the two conjointly. The generic names *Brittonamra, Brittonastrum, Brittonella, Brittonrosea, Bryobrittonia,* and *Neobrittonia* perpetuate his name among botanists. Further to perpetuate his name the periodical "Brittonia" was established as an official serial of the New York Botanical Garden in 1931, devoted to those fields of botanical research in which Doctor Britton was personally interested. In 1935 the great reference herbarium of the New York Botanical Garden was officially designated as the "Britton Herbarium."

The New York Botanical Garden is a constant reminder of the energy, wisdom, scientific attainments, and organization and administrative ability of Nathaniel Lord Britton. His name is indelibly associated with the annals of botany of North and South America and the West Indies. No monument is necessary to perpetuate his name for of him, in association with the great institution he established, it may truly be said: *Si monumentum requiris, circumspice.*

PUBLISHED BIOGRAPHICAL SKETCHES OF NATHANIEL LORD BRITTON

Davis, W. T. Nathaniel Lord Britton. Proc. Staten Island Inst. Arts Sci. 7: 101-108. 1934.

Fernald, M. L. Nathaniel Lord Britton (1859-1934). Proc. Am. Acad. Arts Sci. 70: 505-506. 1936.

Hochreutiner, B. P. G. Un grand naturaliste americain, Nathaniel Lord Britton (1859-1934). Rev. Gen. Sci. 46: 1-2. 1935.

Howe, M. A. Nathaniel Lord Britton. Jour. N. Y. Bot. Gard. 35: 169-180, *portr.*, 1934.

Leon, Hermano. Nathaniel Lord Britton, 1859-1934. Mem. Soc. Cub. Hist. Nat. 8: 345-349. 1935.

Merrill, E. D. Nathaniel Lord Britton. Proc. Linn. Soc. London, 161-165. 1935.

———. Nathaniel Lord Britton. Year Book Am. Philos. Soc. 341-343. 1937.

Noble, W. D. Dr. Nathaniel L. Britton, Biologist. Rev. Obras Publ. Puerto Rico 11: 669-670. 1934.

Nolla, J. A. B. El Doctor Nathaniel Lord Britton. Puerto Rico Illustr. 25: 14-15, 57-58, illus. 1934.

Rusby, H. H. Nathaniel Lord Britton. Science n.s. 80: 108-111. 1934.

Sprague, T. A. Nathaniel Lord Britton. Kew Bull. 275-279. 1934.

BIBLIOGRAPHY

Contributed by John Hendley Barnhart

1877

Staten Island plants. Bull. Torrey Club 6: 177-179. October, 1877.

1878

When the leaves fall. Bull. Torrey Club 6: 211-213. March, 1878.

When the leaves appear. Bull. Torrey Club 6: 235-237. June, 1878.

Staten Island plants. Bull. Torrey Club 6: 259, 260. September, 1878.

1879

The flora of Richmond County, New York. (With Charles Arthur Hollick.) 1-36. [March] 1879.

Notes on the relative age and dimensions of a number of different trees. Bull. Torrey Club 6: 309, 310. May, 1879.

Branched catkins of Salix. Bull. Torrey Club 6: 312. May, 1879.

White strawberry.—Staten Island plants.—Cyperus. Bull. Torrey Club 6: 323. June, 1879.

Notes on Cyperus L. Bull. Torrey Club 6: 339, 340. August, 1879.

1880

Flora of Richmond County, N. Y. Additions and new localities, 1879. (With Charles Arthur Hollick.) Bull. Torrey Club 7: 11, 12. January, 1880.

Juncus maritimus. Bull. Torrey Club 7: 18. February, 1880.

Monstrosity in Carya alba. Bull. Torrey Club 7: 21. February, 1880.

Juncus setaceus. Bull. Torrey Club 7: 36. March, 1880.

Note on the difference between Cyperus ovularis Torr. and C. cylindricus N. L. Britton. Bull. Torrey Club 7: 48, *pl. 3*. April, 1880.

Notes [on mineralogy]. Sch. Mines Quart. 1: 198, 199. May, 1880.

On the northward extension of the N. J. pine barren flora on Long and Staten islands. Bull. Torrey Club 7: 81-83. July, 1880.

Contributions toward a list of the state and local floras of the United States. [I. The eastern states.] (With William Ruggles Gerard.) Bull. Torrey Club 7: 108-111. October, 1880.

1881

Notes on the Middlesex County, N. J., flora. Bull. Torrey Club 8: 7. January, 1881.

Contributions toward a list of the state and local floras of the United States.—Addenda to Part I. (With William Ruggles Gerard.) Bull. Torrey Club 8: 7, 8. January, 1881.

Contributions toward a list of the state and local floras of the United States. II. The middle states. (With William Ruggles Gerard.) Bull. Torrey Club 8: 16-18. February, 1881.

The true geological age of the metamorphic rocks of New York Island and Westchester County. Sch. Mines Quart. 2: 141, 142. March, 1881.

The flora of Richmond County, N. Y.—Additions. (With Charles Arthur Hollick.) Bull. Torrey Club 8: 48. April, 1881.

On the geology of Richmond County, N. Y. [Abstract.] Sch. Mines Quart. 2: 165-173. May, 1881.

On the geology of Richmond County, N. Y. Ann. N. Y. Acad. 2: 161-182, *pl. 15*. May, 1881.

Contributions toward a list of the state and local floras of the United States. The middle states. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 8: 81-83. July, 1881.

A preliminary catalogue of the flora of New Jersey. i-xiii, 1-233. [July] 1881. (Geological Survey of New Jersey.)

White-fruited Mitchella repens. Bull. Torrey Club 8: 111. October, 1881.

Symphoricarpus racemosus Michx. var. pauciflorus Robbins in New York State. Bull. Torrey Club 8: 114. October, 1881.

A large grape-vine. Bull. Torrey Club 8: 116. October, 1881.

Peculiarly-lobed leaves in Quercus alba L. Bull. Torrey Club 8: 126, *f.* November, 1881.

1882

Additional notes on the geology of Staten Island. Trans. N. Y. Acad. 1: 56, 57. 1882.

On a hybrid oak near Keyport, N. J. Bull. Torrey Club 9: 13-15, *pl. 10-12.* February, 1882.

Contributions toward a list of the state and local floras of the United States. III. The south-eastern states. (With William Ruggles Gerard.) Bull. Torrey Club 9: 80-82. June, 1882.

Helonias bullata on Staten Island. Bull. Torrey Club 9: 101. August, 1882.

On some large pot-holes, near Williamsbridge, N. Y. Trans. N. Y. Acad. 1: 181-183. 1882.

Flora of Richmond Co., N. Y. Additions and new localities. (With Charles Arthur Hollick.) Bull. Torrey Club 9: 149-151. December, 1882.

Notes on the autumn flora of southern Wyoming and eastern Colorado. Bull. Torrey Club 9: 156. December, 1882.

1883

[The structure and functions of pollen-grains. Abstract.] Am. Mo. Micr. Jour. 4: 99, 100. May, 1883.

Contributions toward a list of the state and local floras of the United States. IV. The southern states. (With William Ruggles Gerard.) Bull. Torrey Club 10: 67-69. June, 1883.

Pinus Banksiana, Lamb. Bull. Torrey Club 10: 82. July, 1883.

Contributions toward a list of the state and local floras of the United States. V. The western states. (With William Ruggles Gerard.) Bull. Torrey Club 10: 103-105. September, 1883.

Notes on a botanical excursion to Sam's Point, Ulster Co., N. Y. Bull. Torrey Club 10: 105, 106. September, 1883.

On a Post-Tertiary deposit, containing impressions of leaves, in Cumberland County, New Jersey. Proc. Am. Assoc. Adv. Sci. 31: 357-359. [September] 1883.

Notes on the cretaceous marl-belt of New Jersey. [Abstract.] Trans. N. Y. Acad. 2: 9-13. 1883.

On the finding of prehistoric Indian skeletons at Far Rockaway, Long Island. Trans. N. Y. Acad. 2: 140, 141. 1883.

Contributions toward a list of the state and local floras of the United States. The western states. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 10: 129-131. December, 1883.

Melanthium latifolium [in New Jersey]. Bull. Torrey Club 10: 133. December, 1883.

[Fossiliferous sandstones on the beach near Glen Cove, Long Island.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [2]. December, 1883. Also in Science 3: 25. January 4, 1884.

1884

Contributions toward a list of the state and local floras of the United States. The western states. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 11: 9. January, 1884.

Note on Juncus trifidus L. Bull. Torrey Club 11: 20. February, 1884.

A new species of Cyperus. Bull. Torrey Club 11: 29. March, 1884.

A list of plants collected by Mr. J. Albert Rudkin during a trip from Juno, on the coast, to Mt. St. Elias, Alaska, in the summer of 1883. Bull. Torrey Club 11: 36. March, 1884.

Contributions toward a list of the state and local floras of the United States. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 11: 43, 44. April, 1884.

Mertensia virginica. Bull. Torrey Club 11: 45. April, 1884.

Dicentra punctured by humble-bees. Bull. Torrey Club 11: 66, 67. June, 1884.

The range of Phoradendron. Bull. Torrey Club 11: 76. July, 1884.

A list of Cyperaceae collected by the late Mr. S. B. Buckley from 1878 to 1883 in the valley of the lower Rio Grande, in Texas and northern Mexico. Bull. Torrey Club 11: 85-87. August, 1884.

[Corema Conradii.] Bull. Torrey Club 11: 117. October, 1884.

Notes on the moraine at Prince's Bay. [Abstract.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [14]. November, 1884.

On the existence of a peculiar flora on the Kittatinny Mountains of northwestern New Jersey. Bull. Torrey Club 11: 126-128. December, 1884.

The northward range of Penstemon Digitalis Nutt. Bull. Torrey Club 11: 140. December, 1884.

1885

Criticisms on J. Kruttschnitt's papers and preparations relating to pollen-tubes. Jour. N. Y. Micr. Soc. 1: 7-16. January, 1885.

A new Cyperus. Bull. Torrey Club 12: 7, 8. January, 1885.

Contributions toward a list of the state and local floras of the United States. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 12: 26-28. March, 1885.

Fossil leaf of Hausmannia. Jour. N. Y. Micr. Soc. 1: 100. April, 1885.

Contributions toward a list of the state and local floras of the United States. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club 12: 36. April, 1885.

Flora of Richmond Co., N. Y.—Additions, corrections and new localities, 1883-1884. (With Charles Arthur Hollick.) Bull. Torrey Club 12: 38-40. April, 1885.

[The relative progress of this and previous seasons, as indicated by the development of vegetation.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [21]. May, 1885.

Note on Veronica Anagallis L. Bull. Torrey Club **12**: 48, 49. May, 1885.

Notes on the copper mining region of Lake Superior. [Abstract.] Trans. N. Y. Acad. **3**: 13. 1885.

Leaf-bearing sandstones on Staten Island, New York. Trans. N. Y. Acad. **3**: 30, 31. 1885.

Notes and criticisms on Mr. Grant Allen's theory of the origin of leaf-forms. Trans. N. Y. Acad. **3**: 38-44. 1885.

A revision of the North American species of the genus Scleria. Ann. N. Y. Acad. **3**: 228-237. [August] 1885.

Contributions toward a list of the state and local floras of the United States. (Continued.) (With William Ruggles Gerard.) Bull. Torrey Club **12**: 98-100. October, 1885.

[Remarks on a specimen of labradorite.] Proc. Nat. Sci. Assoc. Staten Isl. **1**: [25]. October, 1885.

1886

Southern range of Juncus Greenii Oakes and Tuck. Bull. Torrey Club **13**: 5, 6. January, 1886.

Note on Quercus Muhlenbergii Engelm. Bull. Torrey Club **13**: 40, 41. March, 1886.

[Upon the drift at the south end of the Rapid Transit Railway Tunnel at Tompkinsville.] Proc. Nat. Sci. Assoc. Staten Isl. **1**: [33]. April, 1886.

Flora of Richmond County, N. Y. Additions and new localities, 1885. (With Charles Arthur Hollick.) Bull. Torrey Club **13**: 83, 84. May, 1886.

Leaf-forms of Populus grandidentata. Bull. Torrey Club **13**: 89-91, *pl. 57*. June, 1886.

[The floor of the Triassaic trough. Abstract.] Trans. N. Y. Acad. **5**: 19. 1886.

[The age and nature of the tide-water gneisses. Abstract.] Trans. N. Y. Acad. **5**: 20. 1886.

[Fossil leaves in the Cretaceous clays at Kreisherville, Staten Island. Abstract.] N. Y. Acad. **5**: 28, 29. 1886.

[On the occurrence of a schistose series of crystalline rocks in the Adirondacks. Abstract.] Trans. N. Y. Acad. **5**: 72. 1886.

Geological notes in West Virginia, North Carolina, and eastern Tennessee. Trans. N. Y. Acad. **5**: 215-223. 1886.

Archaean rocks. Geol. Surv. N. J. Ann. Rep. **1885**: 36-55. "1885" [1886].

[The results of a cruise along the shores of Staten Island and New Jersey.] Proc. Nat. Sci. Assoc. Staten Isl. **1**: [38, 39]. September, 1886.

[Additional notes on the geology of Staten Island.] Proc. Nat. Sci. Assoc. Staten Isl. **1**: [40, 41]. October, 1886.

On the species of the genus Anychia Richard. Bull. Torrey Club 13: 185-187. October, 1886.

A preliminary list of North American species of Cyperus, with descriptions of new forms. Bull. Torrey Club 13: 205-216. November, 1886. Also as Contr. Herb. Columbia Coll. no. 1.

1887

Columbia College herbaria. Bot. Gaz. 12: 9-11. January, 1887.

Cerastium arvense L. and its North American varieties. (With Charles Arthur Hollick.) Bull. Torrey Club 14: 45-51, *pl. 63-65*. March, 1887. Also as Contr. Herb. Columbia Coll. no. 2.

[Specimens of fungi collected by members of the Association during the past two years.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [53]. April, 1887.

[Notes upon the relative times of flowering of several shrubs and trees.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [54, 55]. May, 1887.

[Clematis ochroleuca.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [56]. June, 1887.

Note on the flowers of Populus heterophylla L. Bull. Torrey Club 14: 114, 115. June, 1887.

A supposed new genus of Anacardiaceae from Bolivia. Bull. Torrey Club 14: 143. July, 1887.

Notes on the glacial and pre-glacial drifts of New Jersey and Staten Island. Trans. N. Y. Acad. 4: 26-33. 1887.

[The serpentines of the vicinity of New York. Abstract.] Trans. N. Y. Acad. 4: 79. 1887.

Report for 1886 [on Archaean or Primitive rocks]. Geol. Surv. N. J. Ann. Rep. 1886: 74-112, *f. 3-22, 2 maps*. 1887.

Note on the flora of the Kittatinny Mountains. Bull. Torrey Club 14: 187-189. September, 1887.

On recent field work in the Archaean areas of northern New Jersey and southeastern New York. Sch. Mines Quart. 9: 33-39. October, 1887.

1888

[Notes on the modified drift.] Proc. Nat. Sci. Assoc. Staten Isl. 1: [61]. January, 1888.

New or noteworthy North American phanerogams.—I. Bull. Torrey Club 15: 97-105, *pl. 80*. April 2, 1888. Also as Contr. Herb. Columbia Coll. no. 5.

Preliminary catalogue of Anthophyta and Pteridophyta reported as growing spontaneously within one hundred miles of New York City. (With Justus Ferdinand Poggenburg, Emerson Ellick Sterns, Addison Brown, Thomas Conrad Porter, and Charles Arthur Hollick.) 1-xviii, 1-90, *maps*. April 25, 1888.

On an Archaean plant from the white crystalline limestone of Sussex County, N. J. Ann. N. Y. Acad. **4**: 123, 124, *pl. 7*. 1888. Also in Can. Rec. Sci. **3**: 184. July, 1888.

The genus Disporum Salisb. Bull. Torrey Club **15**: 187, 188. July 2, 1888.

Additional notes on the geology of Staten Island. Trans. N. Y. Acad. **6**: 12-18. 1888.

Note on the growth of a vinegar plant in fermented grape juice. Trans. N. Y. Acad. **6**: 66-70. 1888.

A list of plants collected by Miss Mary B. Croft, 1884-'85, at San Diego, Texas, near the headwaters of the Rio Dulce. (With Henry Hurd Rusby.) Trans. N. Y. Acad. **7**: 7-14. 1888. Also as Contr. Herb. Columbia Coll. no. 4.

[A recent boring on Staten Island. Abstract.] Trans. N. Y. Acad. **7**: 39. 1888.

[Survey of a portion of Sussex County.] Geol. Surv. N. J. Ann. Rep. **1887**: 22. "1887" [1888].

Our native pines. Staten Island Mag. **1**: 14-16. August, 1888.

[Botanical nomenclature.] Jour. Bot. **26**: 292-294. October, 1888.

The genus Hicoria of Rafinesque. Bull. Torrey Club **15**: 277-285. November 2, 1888. Also as Contr. Herb. Columbia Coll. no. 7.

1889

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—IV. Anthophyta. Bull. Torrey Club **16**: 13-20. January 12, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—V. Bull. Torrey Club **16**: 61-64. March 8, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

[Recent discovery of another exposure of Cretaceous strata.] Proc. Nat. Sci. Assoc. Staten Isl. **2**: [8]. March, 1889. Also in Am. Nat. **23**: 553. June, 1889.

[Remarks on the yellow gravel or pre-glacial drift.] Proc. Nat. Sci. Assoc. Staten Isl. **2**: [9]. April, 1889. Also in Am. Nat. **23**: 1032, 1033. November, 1889.

Preliminary note on the North American species of the genus Tissa Adans. Bull. Torrey Club **16**: 125-129. May 8, 1889. Also as Contr. Herb. Columbia Coll. no. 11.

Flora of Richmond Co., N. Y.—Additions and new localities, 1886-1889. Appendix no. 5. (With Charles Arthur Hollick.) Bull. Torrey Club **16**: 132-134. May 8, 1889.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—VI. Bull. Torrey Club **16**: 153-160. June 8, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—VII. Bull. Torrey Club **16**: 189-192. July 6, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

Botanical notes. Bull. Torrey Club **16**: 196. July 6, 1889.

[Metamorphic rocks in the vicinity of New York. Abstract.] Trans. N. Y. Acad. **8**: 52, 53. 1889.

A list of plants collected at Fort Verde and vicinity and in the Mogollon and San Francisco mountains, Arizona, 1884-1888, by Dr. E. A. Mearns, U. S. A. Trans. N. Y. Acad. **8**: 61-76. 1889. Also in Contr. Herb. Columbia Coll. no. 9.

Remarks on recent discoveries in local Cretaceous and Quaternary geology. Trans. N. Y. Acad. **8**: 177-181. 1889.

New or noteworthy North American phanerogams, II. Trans. N. Y. Acad. **9**: 6-15. 1889. Also (repaged, 5-14) as Contr. Herb. Columbia Coll. no. 13.

Ferns and their allies, present and past. [Abstract.] Trans. N. Y. Acad. **9**: 26. 1889.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—VIII. Bull. Torrey Club **16**: 259-262. October 5, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

Remarks on the preceding paper. [Cockerell, Theodore Dru Alison. The classification of slight varieties.] Bull. Torrey Club **16**: 272, 273. October 5, 1889.

The genus Eleocharis in North America. Jour. N. Y. Micr. Soc. **5**: 95-111. October, 1889. Also as Contr. Herb. Columbia Coll. no. 12.

[An outcrop of Cretaceous clay at the foot of Eltingville road.] Proc. Nat. Sci. Assoc. Staten Isl. **2**: [17]. October, 1889. Also in Am. Nat. **23**: 1037. November, 1889.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886—IX. Bull. Torrey Club **16**: 324-327. December 10, 1889. Also in Contr. Herb. Columbia Coll. no. 6.

In the hickory matter. Gard. & For. **2**: 621, 622. December 25, 1889.

1890

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—X. Bull. Torrey Club **17**: 9-12. January 15, 1890. Also in Contr. Herb. Columbia Coll. no. 6.

A new species of Rhexia. Bull. Torrey Club **17**: 14, 15, *pl. 99*. January 15, 1890.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XI. Bull. Torrey Club **17**: 53-60. March 10, 1890. Also in Contr. Herb. Columbia Coll. no. 6.

Charles Christopher Parry. Bull. Torrey Club **17**: 74, 75. March 10, 1890.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XII. Bull. Torrey Club **17**: 91-94. April 10, 1890. Also in Contr. Herb. Columbia Coll. no. 6.

A list of state and local floras of the United States and British America. Ann. N. Y. Acad. **5**: 237-262. April, 1890; 263-294. June, 1890; 295-300. July, 1890. Also as Contr. Herb. Columbia Coll. no. 14.

On the naming of "forms," in the New Jersey Catalogue. Bull. Torrey Club **17**: 121-126. May 9, 1890.

Catalogue of plants found in New Jersey. Geol. Surv. N. J., Final Rep. State Geol. **2**: 25-642. "1889" [May, 1890].

Tissa vs. Buda. Bot. Gaz. **15**: 184. July, 1890. Repr. in Jour. Bot. **28**: 295, 296. October, 1890.

The plea of expediency. Bot. Gaz. **17**: 252-254. August, 1890.

List of Staten Island fungi in the collection of the Association. [Determined by Job Bicknell Ellis.] (With Charles Arthur Hollick.) Proc. Nat. Sci. Assoc. Staten Isl. **2**: [58, 59]. August, 1890.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XIII. Bull. Torrey Club **17**: 211-214. August 12, 1890. Also in Contr. Herb. Columbia Coll. no. 6.

Introductory note. In: Newhall, Charles Stedman. The trees of northeastern America. xiv. 1890.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XIV. Bull. Torrey Club **17**: 281-284. November 9, 1890. Also in Contr. Herb. Columbia Coll. no. 6.

[Use of the term "forms."] Proc. Nat. Sci. Assoc. Staten Isl. **2**: 63. November, 1890.

Contributions to Texan botany. Trans. N. Y. Acad. **9**: 181-185. 1890. (Additions to the list of plants collected by Miss Mary B. Croft at San Diego, Texas, 181-183; Note on some plants collected by Mr. Frank Tweedy in Tom Greene Co., Texas, in 1879. 183-185.)

Priority of place in botanical nomenclature. Jour. Bot. **28**: 371, 372. December, 1890.

New or noteworthy North American phanerogams.—III. Bull. Torrey Club **17**: 310-316. December 9, 1890. Also as Contr. Herb. Columbia Coll. no. 16.

Appointment of Dr. Thos. Morong to the curatorship of the Columbia College herbarium. Bull. Torrey Club **17**: 319. December 9, 1890.

On priority of place in biological nomenclature. Bot. Gaz. **15**: 339, 340. December, 1890.

1891

Monographie der Gattung Stylosanthes. Bull. Torrey Club **18**: 25. January 20, 1891. (Review.)

Notes on the leaves of Liriodendron. Bull. Torrey Club **18**: 29, 30. January 20, 1891. (Review.)

Symbolae ad floram Brasiliae centralis cognoscendam. Bull. Torrey Club **18**: 32. January 20, 1891. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XV. Bull. Torrey Club **18**: 35-38. February 12, 1891. Also in Contr. Herb. Columbia Coll. no. 6.

Second systematic census of Australian plants. Bull. Torrey Club **18**: 65. February 12, 1891. (Review.)

Remarks on the genus Actaea. Bull. Torrey Club **18**: 66. February 12, 1891. (Review.)

Reprint of Fraser's Catalogue. Bull. Torrey Club **18**: 71. February 12, 1891. (Review.)

Biographical index to British and Irish botanists. Bull. Torrey Club **18**: 90, 91. March 10, 1891. (Review.)

Catalogue of the Anthophyta and Pteridophyta of Ames, Iowa. Bull. Torrey Club **18**: 91, 92. March 10, 1891. (Review.)

Catalogue of Canadian plants.—Part V. Acrogens. Bull. Torrey Club **18**: 92, 93. March 10, 1891. (Review.)

Ranunculaceae aus dem westlichen Nord Amerika, gesammelt in Auftrage Dr. Dieck's-Zoschen. Bull. Torrey Club **18**: 98, 99. March 10, 1891. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XVI. Bull. Torrey Club **18**: 107-110. April 4, 1891. Also in Contr. Herb. Columbia Coll. no. 6.

Botanical nomenclature. Gard & For. **4**: 202. April 29, 1891.

Flora franciscana. An attempt to classify and describe the vascular plants of middle California. Bull. Torrey Club **18**: 158-160. May 1, 1891. (Review.)

Fungous diseases of the grape and other plants and their treatment. Bull. Torrey Club **18**: 161, 162. May 1, 1891. (Review.)

Notes on North American trees.—XXV. Bull. Torrey Club **18**: 162, 163. May 1, 1891. (Review.)

Report of the botanist of the California State Board of Forestry. Bull. Torrey Club **18**: 164. May 1, 1891. (Review.)

Nebraska flowering plants. Bull. Torrey Club **18**: 195, 196. June 1, 1891. (Review.)

Flora of Richmond Co., N. Y.—Additions and new localities, 1890. Appendix no. 6. (With Charles Arthur Hollick.) Bull. Torrey Club **18**: 213, 214. July 1, 1891.

Revision of the American species of Epilobium occurring north of Mexico. Bull. Torrey Club **18**: 226, 227. July 1, 1891. (Review.)

Beitraege zur Kenntniss der Sapotaceae. Bull. Torrey Club **18**: 227. July 1, 1891. (Review.)

On the general geographical distribution of North American plants. Proc. Am. Assoc. Adv. Sci. **39**: 322-327. July, 1891.

Plantae Europeae. Enumeratio systematica plantarum phanerogamicarum in Europa sponte crescentium vel mere inquilinarum. Bull. Torrey Club **18**: 258, 259. August 8, 1891. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XVII. Bull. Torrey Club **18**: 261-264. September 21, 1891. Also in Contr. Herb. Columbia Coll. no. 6.

New or noteworthy North American phanerogams.—IV. Bull. Torrey Club **18**: 265-272. September 21, 1891. Also as Contr. Herb. Columbia Coll. no. 20.

Notes on the botany of Fernando Noronha. Bull. Torrey Club **18**: 278, 279. September 21, 1891. (Review.)

The genus Corion of Mitchell. Jour. Bot. **29**: 303. October, 1891.

Monographie du genre Chrysosplenium. Bull. Torrey Club **18**: 307. October 8, 1891. (Review.)

Contributions to American botany.—XVIII. Bull. Torrey Club **18**: 310, 311. October 8, 1891. (Review.)

Descriptions of new plants, chiefly Gamopetalae, collected in Mexico by C. G. Pringle. Bull. Torrey Club **18**: 311. October 8, 1891. (Review.)

On the citing of ancient botanical authors. Bull. Torrey Club **18**: 327-330. November 15, 1891.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XVIII. Bull. Torrey Club **18**: 331-334. November 15, 1891. Also in Contr. Herb. Columbia Coll. no. 6.

Iconographia florae japonicae, or Descriptions with figures of plants indigenous to Japan. Bull. Torrey Club **18**: 344. November 15, 1891. (Review.)

[Presidential address.] Proc. Nat. Sci. Assoc. Staten Isl. **3**: [3, 4]. November, 1891.

New or noteworthy North American phanerogams.—V. Bull. Torrey Club **18**: 363-370. December 9, 1891. Also as Contr. Herb. Columbia Coll. no. 22.

List of the plants of Arkansas. Bull. Torrey Club **18**: 377, 378. December 9, 1891. (Review.)

1892

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XIX. Bull. Torrey Club **19**: 1-4. January 15, 1892. Also in Contr. Herb. Columbia Coll. no. 6.

Monographiae phanerogamarum. Vol. vii. Melastomaceae. Bull. Torrey Club **19**: 23. January 15, 1892. (Review.)

Catalogue of the phaenogamous and vascular cryptogamous plants in the vicinity of St. Louis, Mo. Bull. Torrey Club **19**: 66, 67. February 10, 1892. (Review.)

Flora franciscana, Part II. Bull. Torrey Club **19**: 68, 69. February 10, 1892. (Review.)

[The publication of a name as a synonym.] Bull. Torrey Club **19**: 81. March 5, 1892.

Patterson's numbered check-list of North American plants, north of Mexico. Bull. Torrey Club **19**: 101. March 5, 1892. (Review.)

Dictionnaire de botanique. Bull. Torrey Club **19**: 132. April 5, 1892. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XX. Bull. Torrey Club **19**: 148-151. May 5, 1892. Also in Contr. Herb. Columbia Coll. no. 6.

Monographie der Gattung Caltha. Bull. Torrey Club **19**: 156, 157. May 5, 1892. (Review.)

Monograph of the grasses of the United States and British America. Bull. Torrey Club **19**: 163, 164. May 5, 1892. (Review.)

The American species of the genus Anemone and the genera which have been referred to it. Ann. N. Y. Acad. **6**: 215-238. May, 1892. Also as Contr. Herb. Columbia Coll. no. 23.

A list of species of the genera Scirpus and Rynchospora occurring in North America. Trans. N. Y. Acad. **11**: 74-93. 1892. Also (repaged, 1-19) as Contr. Herb. Columbia Coll. no. 26.

New or noteworthy North American phanerogams.—VI. Bull. Torrey Club **19**: 219-226, *pl. 131*. July 13, 1892. Also as Contr. Herb. Columbia Coll. no. 29.

Revision of the American species of Rumex occurring north of Mexico. Bull. Torrey Club **19**: 236. July 13, 1892. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XXI. Bull. Torrey Club **19**: 263-266. September 10, 1892. Also in Contr. Herb. Columbia Coll. no. 6.

Cultivated native plums and cherries. Bull. Torrey Club **19**: 276, 277. September 10, 1892. (Review.)

Portland catalogue of Maine plants—second edition. Bull. Torrey Club **19**: 279. September 10, 1892. (Review.)

Second edition of Webber's appendix to the catalogue of the flora of Nebraska, with a supplementary list of recently reported species. Bull. Torrey Club **19**: 280. September 10, 1892. (Review.)

Silva of North America, Volume IV—Rosaceae-Saxifragaceae. Bull. Torrey Club **19**: 280, 281. September 10, 1892. (Review.)

Dictionary of botanical terms. Bull. Torrey Club **19**: 319, 320. October 10, 1892. (Review.)

Michigan flora. Bull. Torrey Club **19**: 320, 321. October 10, 1892. (Review.)

The ash trees of Staten Island. Proc. Nat. Sci. Assoc. Staten Isl. **3**: [21, 22]. October, 1892.

Some results of a year's work. Bull. Torrey Club **19**: 323. November 15, 1892. (Review.)

Monographie des espèces du genre Fraxinus. Bull. Torrey Club **19**: 342. November 15, 1892. (Review.)

Revision of the North American species of Hoffmanseggia. Bull. Torrey Club **19**: 345. November 15, 1892. (Review.)

Teratological notes. Bull. Torrey Club **19**: 348, 349. November 15, 1892. (Review.)

Ranunculus repens and its eastern North American allies. Trans. N. Y. Acad. **12**: 2-6. November 22, 1892. Also (repaged 1-4) as Contr. Herb. Columbia Coll. no. 30.

An enumeration of the plants collected by Dr. Thomas Morong in Paraguay, 1888-1890. (With Thomas Morong.) Ann. N. Y. Acad. **7**: 45-96. December, 1892; 97-144. January, 1893; 145-192. February, 1893; 193-256. March, 1893; 257-280. April, 1893. Also as Contr. Herb. Columbia Coll. no. 35.

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XXII. Bull. Torrey Club **19**: 371-374. December 15, 1892. Also in Contr. Herb. Columbia Coll. no. 6.

Flora of West Virginia. Bull. Torrey Club **19**: 385, 386. December 15, 1892. (Review.)

Trees of the northern United States, their study, description, and determination, for the use of schools and private students. Bull. Torrey Club **19**: 390, 391. December 15, 1892. (Review.)

1893

On Rusbya, a new genus of Vacciniaceae from Bolivia. Bull. Torrey Club **20**: 67, 68. February 15, 1893.

Contributions from the Botanical Laboratory of the University of Pennsylvania. Bull. Torrey Club **20**: 83, 84. February 15, 1893. (Review.)

Erythea, a journal of botany, West American and general. Bull. Torrey Club **20**: 84, 85. February 15, 1893. (Review.)

[Staten Island trees.] Proc. Nat. Sci. Assoc. Staten Isl. **3**: 34. February, 1893.

The North American species of the genus Lespedeza. Trans. N. Y. Acad. **12**: 57-64. March 10, 1893; 65-68. March 16, 1893. Also as Contr. Herb. Columbia Coll. no. 34.

John Strong Newberry. Bull. Torrey Club **20**: 89-98, *portr., pl. 142.* March 15, 1893.

A neglected species of Hieracium. Bull. Torrey Club **20**: 120, 121, *pl. 145.* March 15, 1893.

Characeae of America. [Part II. Fascicle 1.] Bull. Torrey Club **20**: 130, 131. March 15, 1893. (Review.)

A rearrangement of American Portulaceae. Bull. Torrey Club **20**: 135. March 15, 1893. (Review.)

An enumeration of the plants collected by Dr. H. H. Rusby in South America, 1885-1886.—XXIII. Bull. Torrey Club **20**: 137-140. April 10, 1893. Also in Contr. Herb. Columbia Coll. no. 6.

Enumeration of the plants collected in Bolivia by Miguel Bang, with descriptions of new genera and species. Bull. Torrey Club **20**: 266, 267. June 17, 1893. (Review.)

Note on a collection of Tertiary fossil plants from Potosí, Bolivia. Trans. Am. Inst. Mining Eng. **21**: 250-259, *f.* 1-79. June, 1893. Also (repaged 1-10) as Contr. Herb. Columbia Coll. no. 27.

New or noteworthy North American phanerogams.—VII. Bull. Torrey Club **20**: 277-282, *pl.* 158. July 15, 1893. Also as Contr. Herb. Columbia Coll. no. 38.

Analytical keys to the genera and species of fresh water algae and the Desmidiae of the United States. Bull. Torrey Club **20**: 300. July 15, 1893. (Review.)

A synopsis of the genera and species of Museae. Bull. Torrey Club **20**: 343. August 10, 1893. (Review.)

The North American Sileneae and Polycarpae. Bull. Torrey Club **20**: 343, 344. August 10, 1893. (Review.)

Preliminary contribution to our knowledge of the cretaceous formation on Long Island and eastwards. Bull. Torrey Club **20**: 345. August 10, 1893. (Review.)

Plant distribution as a factor in the interpretation of geological phenomena, with special reference to Long Island and vicinity. Bull. Torrey Club **20**: 345. August 10, 1893. (Review.)

The genus Trematocarpus. Bull. Torrey Club **20**: 347. August 10, 1893. (Review.)

Organization of a society of American botanists. Erythea **1**: 219, 220. October 2, 1893.

The use of the generic name Halesia. Gard. & For. **6**: 433, 434. October 18, 1893.

The generic name of the silver-bell trees. Gard. & For. **6**: 463. November 8, 1893.

Duplicate binomials. Bull. Torrey Club **20**: 443. November 15, 1893.

Gymnospermae [of northeastern North America]. Mem. Torrey Club **5**: 17-19. December 4, 1893.

Halesia vs. Mohria vel Mohrodendron. Gard. & For. **6**: 518. December 13, 1893.

1894

New or noteworthy North American phanerogams.—VIII. Bull. Torrey Club **21**: 27-34, *pl.* 173. January 25, 1894. Also as Contr. Herb. Columbia Coll. no. 47.

Botany of the Death Valley Expedition. Bull. Torrey Club **21**: 45, 46. January 25, 1894. (Review.)

Enumeratio Myrtacearum brasiliensium. Bull. Torrey Club **21**: 47. January 25, 1894. (Review.)

Cyperaceae [of northeastern North America], with the exception of Carex. Mem. Torrey Club **5**: 59-70. January 31, 1894.

Note on the herbarium of Stephen Elliott. Bull. Torrey Club **21**: 80, 81. February 20, 1894.

Die Delphinium Arten der Vereinigten Staaten von Nord Amerika. Bull. Torrey Club **21**: 82, 83. February 20, 1894. (Review.)

Our conception of "species" as modified by the doctrine of evolution. Trans. N. Y. Acad. **13**: 132-135. March 20, 1894. Also as Contr. Herb. Columbia Coll. no. 51.

Professor Greene and Jacksonia and Polanisia. Erythea **2**: 67, 68. April 1, 1894.

The herbarium of the late Isaac C. Martindale. Bull. Torrey Club **21**: 176. April 25, 1894.

Manual of the botany of the region of San Francisco Bay. Bull. Torrey Club **21**: 179-181. April 25, 1894. (Review.)

Juncus marginatus and its varieties. Bull. Torrey Club **21**: 181. April 25, 1894. (Review.)

Annual reports of the State Botanist of the state of New York. Bull. Torrey Club **21**: 181, 182. April 25, 1894. (Review.)

Neue Asiatische und Amerikanische Gentianien. Bull. Torrey Club **21**: 182. April 25, 1894. (Review.)

Aizoaceae [of northeastern North America]. Mem. Torrey Club **5**: 147. April 27, 1894.

Portulacaceae [of northeastern North America]. Mem. Torrey Club **5**: 147. April 27, 1894.

Caryophyllaceae [of northeastern North America]. Mem. Torrey Club **5**: 148-152. April 27, 1894; 153. May 5, 1894.

Ranunculaceae [of northeastern North America]. Mem. Torrey Club **5**: 155-162. May 5, 1894.

Berberidaceae [of northeastern North America]. Mem. Torrey Club **5**: 162. May 5, 1894.

Menispermaceae [of northeastern North America]. Mem. Torrey Club **5**: 162, 163. May 5, 1894.

Papaveraceae [of northeastern North America]. Mem. Torrey Club **5**: 164-166. May 5, 1894.

Cruciferae [of northeastern North America]. Mem. Torrey Club **5**: 166-168. May 5, 1894; 169-175. May 21, 1894.

Capparidaceae [of northeastern North America]. Mem. Torrey Club **5**: 175. May 21, 1894.

Sarraceniaceae [of northeastern North America]. Mem. Torrey Club **5**: 176. May 21, 1894.

Saxifragaceae [of northeastern North America]. Mem. Torrey Club **5**: 177-180. May 21, 1894.

Hamamelidaceae [of northeastern North America]. Mem. Torrey Club **5**: 180, 181. May 21, 1894.

Rosaceae [of northeastern North America]. Mem. Torrey Club **5**: 181-184. May 21, 1894; 185-191. May 29, 1894.

A new systematic botany of North America. Bull. Torrey Club **21**: 230, 231. May 25, 1894.

Crataegus punctata canescens n. var. Bull. Torrey Club **21**: 231, 232. May 25, 1894.

Leguminosae [of northeastern North America]. Mem. Torrey Club **5**: 191-200. May 29, 1894; 201-209. June 14, 1894.

[Recent discovery of three species of Barbarea on Staten Island.] Proc. Nat. Sci. Assoc. Staten Isl. **4**: 32. June, 1894.

Limnanthaceae [of northeastern North America]. Mem. Torrey Club **5**: 216. June 14, 1894.

Anacardiaceae [of northeastern North America]. Mem. Torrey Club **5**: 216. June 14, 1894.

Thomas Morong. Bull. Torrey Club **21**: 239-244. June 20, 1894.

A revision of the genus Lechea. Bull. Torrey Club **21**: 244-253. June 20, 1894. Also as Contr. Herb. Columbia Coll. no. 56.

Synopsis of Malveae, or an enumeration of the plants contained in the first tribe of the natural order Malvaceae. Bull. Torrey Club **21**: 270. June 20, 1894. (Review.)

Cyrillaceae [of northeastern North America]. Mem. Torrey Club **5**: 217. June 23, 1894.

Aquifoliaceae [of northeastern North America]. Mem. Torrey Club **5**: 217. June 23, 1894.

Elatineaceae [of northeastern North America]. Mem. Torrey Club **5**: 225, 226. June 23, 1894.

Cistaceae [of northeastern North America]. Mem. Torrey Club **5**: 226. June 23, 1894.

Violaceae [of northeastern North America]. Mem. Torrey Club **5**: 227, 228. June 23, 1894.

Onagraceae [of northeastern North America]. Mem. Torrey Club **5**: 232. June 23, 1894; 233-236. July 7, 1894.

Hydrocaryaceae [of northeastern North America]. Mem. Torrey Club **5**: 237. July 7, 1894.

Araliaceae [of northeastern North America]. Mem. Torrey Club **5**: 238. July 7, 1894.

Umbelliferae [of northeastern North America]. Mem. Torrey Club **5**: 238-245. July 7, 1894.

Ericaceae [of northeastern North America]. Mem. Torrey Club **5**: 248. July 7, 1894; 249-258. July 18, 1894.

Plumbaginaceae [of northeastern North America]. Mem. Torrey Club **5**: 255, 256. July 18, 1894.

Styraceae [of northeastern North America]. Mem. Torrey Club **5**: 256, 257. July 18, 1894.

Oleaceae [of northeastern North America]. Mem. Torrey Club **5**: 257, 258. July 18, 1894.

Loganiaceae [of northeastern North America]. Mem. Torrey Club **5**: 258. July 18, 1894.

Gentianaceae [of northeastern North America]. Mem. Torrey Club **5**: 258-262. July 18, 1894.

Apocynaceae [of northeastern North America]. Mem. Torrey Club **5**: 262, 263. July 18, 1894.

Asclepiadaceae [of northeastern North America]. Mem. Torrey Club **5**: 263, 264. July 18, 1894; 265, 266. August 13, 1894.

Note on the genus Enslenia Nutt. Bull. Torrey Club **21**: 314. July 20, 1894.

Convolvulaceae [of northeastern North America]. Mem. Torrey Club **5**: 266-268. August 13, 1894.

Cuscutaceae [of northeastern North America]. Mem. Torrey Club **5**: 268, 269. August 13, 1894.

Polemoniaceae [of northeastern North America]. Mem. Torrey Club **5**: 269, 270. August 13, 1894.

Boraginaceae [of northeastern North America]. Mem. Torrey Club **5**: 272-276. August 13, 1894.

Verbenaceae [of northeastern North America]. Mem. Torrey Club **5**: 276, 277. August 13, 1894.

Labiatae [of northeastern North America]. Mem. Torrey Club **5**: 277-280. August 13, 1894; 281-286. August 28, 1894.

Solanaceae [of northeastern North America]. Mem. Torrey Club **5**: 287-289. August 28, 1894.

Scrophulariaceae [of northeastern North America]. Mem. Torrey Club **5**: 289-296. August 28, 1894; 297. October 10, 1894.

Orobanchaceae [of northeastern North America]. Mem. Torrey Club **5**: 298, 299. October 10, 1894.

Bignoniaceae [of northeastern North America]. Mem. Torrey Club **5**: 299. October 10, 1894.

Pedaliaceae [of northeastern North America]. Mem. Torrey Club **5**: 299. October 10, 1894.

Acanthaceae [of northeastern North America]. Mem. Torrey Club **5**: 300, 301. October 10, 1894.

Rubiaceae [of northeastern North America]. Mem. Torrey Club **5**: 301-304. October 10, 1894.

Caprifoliaceae [of northeastern North America]. Mem. Torrey Club **5**: 304-306. October 10, 1894.

Adoxaceae [of northeastern North America]. Mem. Torrey Club **5**: 307. October 10, 1894.

Valerianaceae [of northeastern North America]. Mem. Torrey Club **5**: 307, 308. October 10, 1894.

Campanulaceae [of northeastern North America]. Mem. Torrey Club **5**: 309, 310. October 10, 1894.

Compositae [of northeastern North America]. (With Thomas Conrad Porter.) Mem. Torrey Club **5**: 310-312. October 10, 1894; 313-328. October 27, 1894; 329-344. November 17, 1894; 345, 346. December 16, 1894.

The Columbia College Herbarium. Bull. Torrey Club **21**: 491. November 24, 1894.

An enumeration of the plants collected by Dr. Timothy E. Wilcox, U. S. A., and others in southeastern Arizona during the years 1892-1894. (With Thomas Henry Kearney.) Trans. N. Y. Acad. **14**: 21-32. December 4, 1894; 33-44. January 26, 1895. Also as Contr. Herb. Columbia Coll. no. 71.

Cichoriaceae [of northeastern North America]. (With Thomas Conrad Porter.) Mem. Torrey Club **5**: 346-351. December 16, 1894.

Flora of Nebraska. Bull. Torrey Club **21**: 534. December 24, 1894. (Review.)

1895

Flora of Nebraska. Science II. **1**: 25, 26. January 4, 1895. (Review.)

Grasses of Tennessee—Part II. Science II. **1**: 55. January 11, 1895. (Review.)

Annual report of the State Botanist of New York. Bull. Torrey Club **22**: 82. February 26, 1895. (Review.)

Publication by signatures. Erythea **3**: 50-52. March 1, 1895.

Notes on the primary foliage and the leaf-scars in Pinus rigida. [Abstract.] Proc. Am. Assoc. Adv. Sci. **43**: 293. March, 1895.

[Publication by signatures.] Erythea **3**: 68. April 1, 1895.

The Systematic Botany of North America. Bot. Gaz. **20**: 177-179. April 20, 1895.

An enumeration of the plants collected by M. E. Penard in Colorado during the summer of 1892. (With Anna Murray Vail.) Bull. Herb. Boissier **3**: 197-221. May, 1895. Also as Contr. Herb. Columbia Coll. no. 75.

Conopholis americana (L.f.) Wallr. Proc. Nat. Sci. Assoc. Staten Isl. **4**: 76. May, 1895.

Field, forest and garden botany. Science II. **1**: 527. May 10, 1895. (Review.)

New or noteworthy North American phanerogams.—IX. Bull. Torrey Club **22**: 220-225. May 15, 1895. Also as Contr. Herb. Columbia Coll. no. 77.

A handbook of systematic botany. Science II. **1**: 550-552. May 17, 1895. (Review.)

The generic name of the water-weed. Science II. **2**: 5. July 5, 1895.

Daniel Cady Eaton. Science II. **2**: 57, 58. July 19, 1895.

Catalogue of Ohio plants. Bull. Torrey Club **22**: 336. July 31, 1895. (Review.)

The London catalogue of British plants. Bull. Torrey Club **22**: 404-407. September 30, 1895. (Review.)

Flora of Richmond Co., N. Y. Additions and new localities, 1891-1895. Appendix, no. 7. (With Charles Arthur Hollick.) Bull. Torrey Club **22**: 460-462. November 30, 1895.

Two new botanical serials. Bull. Torrey Club **22**: 470, 471. November 30, 1895.

Additions to and new localities for the local flora. Proc. Nat. Sci. Assoc. Staten Isl. **5**: 11. December, 1895.

1896

[The origin and relations of the floras and faunas of the Antarctic and adjacent regions.] Botany. Science II. **3**: 310, 311. February 28, 1896.

Report of the Secretary for 1915. Bull. N. Y. Bot. Gard. **1**: 10-17. April 15, 1896.

Notes on the ninth edition of the London catalogue of British plants. Bull. Torrey Club **23**: 215-217. May 30, 1896. (Review.)

The herbarium of Columbia University, and the herbarium of the New York Botanical Garden. Bull. Torrey Club **23**: 253. June 30, 1896.

An illustrated flora of the northern United States, Canada and the British possessions. Vol. I. Ophioglossaceae to Aizoaceae. (With Addison Brown.) i-xii, 1-612, *f. 1-1425*. [August 15] 1896.

Botanical gardens. Science II. **4**: 284-293. September 4, 1896. Printed, in part, in Gard. & For. **9**: 352, 353. September 2, 1896; 362, 363. September 9, 1896. Reprinted in Bull. Torrey Club **23**: 331-345. September 25, 1896. Reprinted in Bull. N. Y. Bot. Gard. **1**: 62-77. January 1, 1897. Reprinted in Proc. Am. Assoc. Adv. Sci. **45**: 171-184. January, 1897.

An Eleocharis new to North America. [Abstract.] Bot. Gaz. **22**: 219, 220. September 23, 1896.

On Crataegus coccinea and its segregates. [Abstract.] Bot. Gaz. **22**: 222. September 23, 1896. Also in Science II. **4**: 431. September 25, 1896.

Notes on the genus Amelanchier. [Abstract.] Bot. Gaz. **22**: 234, 235. September 23, 1896. Also in Science II. **4**: 431. September 25, 1896.

Some Cyperaceae new to North America, with remarks on other species. [Abstract.] Bot. Gaz. **22**: 238. September 23, 1896. Also in Science II. **4**: 431. September 25, 1896.

On the cardamines of the C. hirsuta group. [Abstract.] Bot. Gaz. **22**: 239. September 23, 1896. Also in Science II. **4**: 431. September 25, 1896.

1897

Les jardins botaniques. Rev. Sci. IV. **7**: 10-15. January 2, 1897.

Crataegus Vailiae n.sp. Bull. Torrey Club **24**: 53. January 28, 1897.

Two undescribed eastern species. Bull. Torrey Club **24**: 92, 93. February 28, 1897.

The metric system and the "Illustrated flora." Bot. Gaz. **23**: 204, 205. March 24, 1897.

The American cowslip. Am. Gard. **18**: 373, 374, *f. 104*. May 22, 1897.

An illustrated flora of the northern United States, Canada and the British possessions. Vol. II. Portulacaceae to Menyanthaceae. (With Addison Brown.) i-iv, 1-643, *f. 1426-2892.* [May 31] 1897.

Nomenclaturregeln fur die Beamten des Königlichen Botanischen Gartens und Museums zu Berlin. Bull. Torrey Club **24**: 415-419. August 29, 1897. (Review.)

1898

Report of the Secretary and Director-in-Chief [for 1896]. Bull. N. Y. Bot. Gard. 1: 106-113. February 15, 1898.

Report of the Secretary and Director-in-Chief [for 1897]. Bull. N. Y. Bot. Gard. 1: 122-127. February 15, 1898.

An illustrated flora of the northern United States, Canada and the British possessions. Vol. III. Apocynaceae to Compositae. (With Addison Brown.) i-xiv, 1-588, *f. 2893-4081,* and *81 f.* numbered from *1a* to *3875a.* 1898.

An illustrated flora of the northern United States, Canada and the British possessions. General key and indexes to the three volumes. (With Addison Brown.) i-xiv, 17-83. 1898.

A buried forest near Giffords. Proc. Nat. Sci. Assoc. Staten Isl. 7: 2. November, 1898.

1899

Introduction. In: Lounsberry, Alice. A guide to the wild flowers. xv-xviii. 1899.

Report of the Secretary and Director-in-Chief [for 1898]. Bull. N. Y. Bot. Gard. 1: 171-184. April 13, 1899.

Description of a new stonecrop from Mexico. Bull. N. Y. Bot. Gard. 1: 257. April 13, 1899.

1900

The Museum Building. Jour. N. Y. Bot. Gard. 1: 1-5, *pl. 1.* January, 1900.

Report of the Secretary and Director-in-Chief [for 1899]. Bull. N. Y. Bot. Gard. 1: 295-310. March 30, 1900.

Descriptions of new North American thorns. Bull. N. Y. Bot. Gard. 1: 447-449. March 30, 1900.

Introduction. In: Lounsberry, Alice. A guide to the trees. xix, xx. [April] 1900.

The button-bush a tree. Jour. N. Y. Bot. Gard. 1: 54, *f. 11.* April, 1900.

Dr. Torrey as a botanist. Bull. Torrey Club **27**: 540-551. October 26, 1900.

Report of the Director-in-Chief on results of his trip to Europe, 1900. Jour. N. Y. Bot. Gard. 1: 177-183. December, 1900.

Report on exploration and collection during 1900. Jour. N. Y. Bot. Gard. 1: 183, 184. December, 1900.

Report on the Conservatory Fund. Jour. N. Y. Bot. Gard. 1: 184, 185. December, 1900.

1901

Weeping American aspens. Jour. N. Y. Bot. Gard. 2: 12, 13, *f. 2.* January, 1901.

Notes on Rudbeckia hirta L. Torreya 1: 1, 2. January 29, 1901.

A new Senecio from Pennsylvania. Torreya 1: 21. February 23, 1901.

La flore du Klondike. Actes Congr. Internat. Bot. Paris 1900. 276. "1900" [1901].

The Morong herbarium. Jour. N. Y. Bot. Gard. 2: 35-37. March, 1901.

The application of precedence of place in nomenclature. Science II. 13: 588, 589. April 12, 1901.

A new hawkweed from Florida. Torreya 1: 41, 42. April 19, 1901.

A new Crataegus from Washington. Torreya 1: 55. May 22, 1901.

Report of the Secretary and Director-in-Chief [for 1900]. Bull. N. Y. Bot. Gard. 2: 1-24. May 27, 1901.

An enumeration of the flowering plants collected by R. S. Williams and J. B. Tarleton [in the Yukon Territory]. (With Per Axel Rydberg.) Bull. N. Y. Bot. Gard. 2: 149-187. May 27, 1901.

Judge Daly's sunflower. Jour. N. Y. Bot. Gard. 2: 87-90. June, 1901.

Thomas Conrad Porter. Bull. Torrey Club 28: 369-373, *portr.* July, 1901.

Nocca and Cracca. Torreya 1: 83. July 13, 1901.

Manual of the flora of the northern states and Canada. i-x, 1-1080. [October] 1901. [Second impression], i-xxiv, 1-1080. "1901" [February, 1902].

Report by the Director-in-Chief on his recent trip to the West Indies. Jour. N. Y. Bot. Gard. 2: 161-166. November, 1901.

Cupania on Pine Key, Florida. Torreya 1: 132. November 25, 1901.

1902

The preservation of native plants. Jour. N. Y. Bot. Gard. 3: 1-3. January, 1902.

A New Mouriria from Porto Rico. Torreya 2: 10. January 24, 1902.

Completion of the Public Conservatories. Jour. N. Y. Bot. Gard. 3: 23-27, *illust.* February, 1902.

A new Peperomia from the island of St. Kitts. Torreya 2: 43. March 12, 1902.

Report of the Secretary and Director-in-Chief for the year 1901. Bull. N. Y. Bot. Gard. 2: 235-267. April 25, 1902.

The collection of tree-ferns. Jour. N. Y. Bot. Gard. 3: 109, 110, *pl. 10.* June, 1902.

An undescribed species of Hydrophyllum. Torreya 2: 123. August 2, 1902.

Results of the use of the Stokes Fund for the preservation of native plants. Jour. N. Y. Bot. Gard. 3: 179, 180. October, 1902.

Driveways, paths, and grading. Jour. N. Y. Bot. Gard. 3: 206, 207. November, 1902.

Report of the Director-in-Chief on his visit to the Royal Gardens, Kew. Jour. N. Y. Bot. Gard. 3: 223, 224. December, 1902.

1903

Resident research scholarships at the New York Botanical Garden. Jour. N. Y. Bot. Gard. 4: 25, 26. February, 1903.

An undescribed Eleocharis from Pennsylvania. Torreya 3: 23, 24, *f. 1, 2.* February 19, 1903.

Research funds of the Scientific Alliance of New York. Science II. 17: 314, 315. February 20, 1903.

The Bronx Park Station of the Manhattan Railway. Jour. N. Y. Bot. Gard. 4: 41-44, *f. 1.* March, 1903.

Report of the Secretary and Director-in-Chief for the year 1902. Bull. N. Y. Bot. Gard. 2: 409-437. March 18, 1903.

Timothy Field Allen. Bull. Torrey Club 30: 173-177, *portr.* April 8, 1903.

A new species of Urera. Torreya 3: 90, 91. June 12, 1903.

Report of the Director-in-Chief upon exploration in Cuba. Jour. N. Y. Bot. Gard. 4: 95-99, *f. 12, 13.* June, 1903.

A new Lippia from Porto Rico. Torreya 3: 105. July 25, 1903.

A new Waltheria from the Bahamas. Torreya 3: 105, 106. July 25, 1903.

New paths at the southern end of the Garden. Jour. N. Y. Bot. Gard. 4: 128, 129. August, 1903.

The "Newell Avenue" bridge. Jour. N. Y. Bot. Gard. 4: 132, *f. 17.* August, 1903.

New or noteworthy North American Crassulaceae. (With Joseph Nelson Rose.) Bull. N. Y. Bot. Gard. 3: 1-45. November 11, 1903. Issued separately in advance, September 12, 1903.

A new appropriation for construction. Jour. N. Y. Bot. Gard. 4: 149, 150. September, 1903.

Report on Cuban exploration. Jour. N. Y. Bot. Gard. 4: 193, 194. November, 1903.

Flora of the southeastern United States. Jour. N. Y. Bot. Gard. 4: 215, 216. November, 1903. (Review.)

The rose mallows. Jour. N. Y. Bot. Gard. 4: 219, 220, *pl. 17, 18.* December, 1903.

Cornelius Van Brunt. Torreya 3: 177-179, *portr.* December 22, 1903.

1904

The honeysuckles. Science II. 19: 145, 146. January 22, 1904. (Review.)

The tropical station at Cinchona, Jamaica. Jour. N. Y. Bot. Gard. 5: 1-7, *f. 1, 2; pl. 19.* January, 1904. Reprinted (slightly abridged) in Pop. Sci. Mo. 64: 426-430. March, 1904.

Olivia and Caroline Phelps Stokes fund for the protection of native plants. Jour. N. Y. Bot. Gard. 5: 7, 8. January, 1904.

George Washington's palms. Jour. N. Y. Bot. Gard. 5: 25-28, *pl. 20, 21.* February, 1904.

Botanical exploration of the Philippine Islands. Jour. N. Y. Bot. Gard. 5: 40, 41. February, 1904.

The Juncaceae of the West Indies. Torreya 4: 23. February 25, 1904.

Agdestis clematidea Moc. & Sessé. Torreya 4: 24. February 25, 1904.

Crataegus Porteri Britton. Torreya 4: 39, 40. March 12, 1904.

The birch trees of North America. [Abstract.] Torreya 4: 46. March 12, 1904.

Four new North American birches. Bull. Torrey Club 31: 165, 166. March 12, 1904.

Report of the Secretary and Director-in-Chief for the year 1903. Bull. N. Y. Bot. Gard. 3: 175-206. March 22, 1904.

Viburnum molle Michx. Torreya 4: 69. May 13, 1904.

Scirpus coloradoensis sp. nov. Torreya 4: 93. June 8, 1904.

Explorations in Florida and the Bahamas. Jour. N. Y. Bot. Gard. 5: 129-136, *f. 18-23.* July, 1904.

Savia bahamensis sp. nov. Torreya 4: 104, 105. July 21, 1904.

Explorations in Florida and the Bahamas. [Abstract.] Torreya 4: 106, 107. July 21, 1904.

An undescribed species of Alnus. Torreya 4: 124. August 27, 1904.

A new species of Bradburya. Torreya 4: 142. September 30, 1904.

Lenophyllum, a new genus of Crassulaceae. (With Joseph Nelson Rose.) Smithson. Misc. Coll. 47: 159-162, *f. 18, 19; pl. 20.* October 10, 1904. Also as Smithson. Inst. Publ. no. 1479.

The Florida royal palm. Torreya 4: 152. October 29, 1904.

Report on exploration of the Bahamas. Jour. N. Y. Bot. Gard. 5: 201-209, *f. 36-39.* November, 1904.

Rynchospora Pringlei Greenman. Torreya 4: 170. November 21, 1904.

On Pisonia obtusata and its allies. Bull. Torrey Club 31: 611-615. November 26, 1904. Also as Contr. N. Y. Bot. Gard. no. 61.

Notes on the flora of the Bahamas. [Abstract.] Torreya 4: 190, 191. December 30, 1904.

1905

Carex Underwoodii sp. nov. Torreya 5: 10, 11. January 19, 1905.

Contributions to the flora of the Bahama Islands.—I. Bull. N. Y. Bot. Gard. 3: 441-453. April 14, 1905. Issued separately in advance, February 7, 1905.

Galactia Curtissii sp. nov. Torreya 5: 33, 34. February 28, 1905.

Jacquinia Curtissii sp. nov. Torreya 5: 44. March 22, 1905.

Manual of the flora of the northern states and Canada. Second edition. i-xxiv, 1-1112. [April] 1905. [Second impression.] i-xxiv, 1-1122. [November] 1907.

A botanical cruise in the Bahamas. [Abstract.] Torreya **5**: 71, 72. April 27, 1905.

Report of the Secretary and Director-in-Chief for the year 1904. Bull. N. Y. Bot. Gard. **4**: 1-17. May 8, 1905.

Crassulaceae. (With Joseph Nelson Rose.) N. Am. Flora **22**: 7-74. May 22, 1905.

The North American Flora. Jour. N. Y. Bot. Gard. **6**: 77, 78. May, 1905.

Explorations in the Bahamas. Jour. N. Y. Bot. Gard. **6**: 78-85, *f. 17-21.* May, 1905.

The Olivia and Caroline Phelps Stokes fund for the protection of native plants. Jour. N. Y. Bot. Gard. **6**: 102. June, 1905.

Report on a trip to Europe. Jour. N. Y. Bot. Gard. **6**: 123-129. August, 1905.

Nomenclature at the Vienna international botanical congress. Science II. **22**: 217-219. August 18, 1905.

Contributions to the flora of the Bahama Islands.—II. Bull. N. Y. Bot. Gard. **4**: 115-127. June 25, 1906. Issued separately in advance, August 24, 1905.

The fountain in front of the Museum Building. Jour. N. Y. Bot. Gard. **6**: 140-144. September, 1905.

A lost species of Begonia apparently rediscovered. Jour. N. Y. Bot. Gard. **6**: 146-148, *f. 33.* September, 1905.

Bermuda in September. Jour. N. Y. Bot. Gard. **6**: 153-158, *pl. 29, 30.* October, 1905.

Cunoniaceae. N. Am. Flora **22**: 179, 180. December 18, 1905.

Iteaceae. N. Am. Flora **22**: 181. December 18, 1905.

Hamamelidaceae. N. Am. Flora **22**: 185-187. December 18, 1905.

1906

The Cuban columneas. Torreya **5**: 215. January 10, 1906.

Further remarks on the vegetation of the Bahamas. [Abstract.] (With Charles Frederick Millspaugh.) Torreya **5**: 219, 220. January 10, 1906.

Circular relative to membership. Jour. N. Y. Bot. Gard. **7**: 1. January, 1906.

The Students Research Fund. Jour. N. Y. Bot. Gard. **7**: 1, 2. January, 1906.

Additional members of the Garden staff. Jour. N. Y. Bot. Gard. **7**: 4, 5. January, 1906.

The North American Cactaceae. [Abstract.] Torreya **6**: 12-14. January 25, 1906.

Report of the Secretary and Director-in-Chief for the year 1905. Bull. N. Y. Bot. Gard. **5**: 1-15. February 13, 1906.

Notes on West Indies Cruciferae. Torreya **6**: 29-32. February 19, 1906.

Progress of construction work during the winter. Jour. N. Y. Bot. Gard. **7**: 23, 24. February, 1906.

Contributions to the flora of the Bahama Islands.—III. Bull. N. Y. Bot. Gard. 4: 137-143. June 25, 1906. Issued separately in advance, March 19, 1906.

The classification of Cactaceae. Jour. Hort. Soc. N. Y. 1: 15. April, 1906. Reprinted in Pl. World 9: 171, 172. July, 1906.

The hemlock grove on the banks of the Bronx River and what it signifies. Trans. Bronx Soc. Arts Sci. 1: 5-13. May, 1906. Also as Contr. N. Y. Bot. Gard. no. 83.

Recent botanical explorations in Porto Rico. Jour. N. Y. Bot. Gard. 7: 125-139, *f. 4-12.* May, 1906.

A large oak struck by lightning. Jour. N. Y. Bot. Gard. 7: 154-156, *f. 20.* June, 1906.

First grant from the Students' Research Fund. Jour. N. Y. Bot. Gard. 7: 157, 158. June, 1906.

Galactia Odonia Griseb. Torreya 6: 149. July 25, 1906.

Recent explorations in Jamaica. Jour. N. Y. Bot. Gard. 7: 245-250, *f. 43.* November, 1906.

Nature study work of the public schools. Jour. N. Y. Bot. Gard. 7: 274, 275. December, 1906.

1907

Two undescribed species of Comocladia from Jamaica. Torreya 7: 6, 7. February 7, 1907.

The sedges of Jamaica. [Abstract.] Torreya 7: 17, 18. February 7, 1907.

A new polygalaceous tree of Porto Rico. Torreya 7: 38, 39. February 28, 1907.

Report of the Secretary and Director-in-Chief for the year 1906. Bull. N. Y. Bot. Gard. 5: 195-213. March 7, 1907.

[Pioneers of science in America.] John Torrey. Pop. Sci. Mo. 70: 297, 299, *portr.* April, 1907.

Report on the continuation of the botanical exploration of the Bahama Islands. Jour. N. Y. Bot. Gard. 8: 71-81. April, 1907.

Ribes chihuahuense sp. nov. Torreya 7: 102. May 20, 1907.

Address delivered at the dedication to Linnaeus of the Pelham Parkway bridge over the Bronx River. Jour. N. Y. Bot. Gard. 8: 136-138, *f. 20.* June, 1907.

Further remarks on the botanical exploration of the Bahamas. [Abstract.] Torreya 7: 154, 155. July 19, 1907.

Erythroxylaceae. N. Am. Flora 25: 59-66. August 24, 1907.

The sedges of Jamaica. Bull. Dep. Agr. Jamaica 5: Suppl. 1-19. September 19, 1907. Also as Contr. N. Y. Bot. Gard. no. 97.

Further exploration in Jamaica. Jour. N. Y. Bot. Gard. 8: 229-236. October, 1907.

Contributions to the flora of the Bahama Islands.—IV. Bull. N. Y. Bot. Gard. **5**: 311-318. February 8, 1909. Issued separately in advance, October 26, 1907.

Pereskiopsis, a new genus of Cactaceae. (With Joseph Nelson Rose.) Smithson. Misc. Coll. **50**: 331-333, *pl. 43, 44*. October 28, 1907. Also as Smithson. Inst. Publ. no. 1775.

The Boulder Bridge. Jour. N. Y. Bot. Gard. **8**: 247-250. November, 1907.

Lucien Marcus Underwood. Columbia Univ. Quart. **10**: 67-69, *portr.* December, 1907.

1908

Botanical exploration in Jamaica. [Abstract.] Torreya **7**: 238. January 16, 1908.

Address by the president of the Academy [at the celebration of the bicentenary of the birth of Linnaeus]. Ann. N. Y. Acad. **18**: 40, 41. January, 1908.

The herbarium of the late Dr. Otto Kuntze. Jour. N. Y. Bot. Gard. **9**: 19-21. February, 1908.

A preliminary treatment of the Opuntioideae of North America. (With Joseph Nelson Rose.) Smithson. Misc. Coll. **50**: 503-539. February 20, 1908. Also as Smithson. Inst. Publ. no. 1786.

Report of the Secretary and Director-in-Chief for the year 1907. Bull. N. Y. Bot. Gard. **6**: 1-21. February 24, 1908.

Professor Underwood's relation to the work of the New York Botanical Garden. Bull. Torrey Club **35**: 39, 40. February 29, 1908.

[Wild Jamaica cotton.] Science II. **27**: 665. April 24, 1908. Reprinted in Torreya **8**: 230, 231. September 26, 1908.

The genus Ernodea Swartz: a study of species and races. Bull. Torrey Club **35**: 203-208. April 29, 1908. Also as Contr. N. Y. Bot. Gard. no. 106.

North American trees. (With John Adolph Shafer.) i-x, 1-894, *f. 1-781*. "April" [May 9] 1908.

Botanical exploration in Jamaica. Jour. N. Y. Bot. Gard. **9**: 81-90. May, 1908.

The taxonomic aspect of the species question. Am. Nat. **42**: 225-242. May 18, 1908. Also as Contr. N. Y. Bot. Gard. no. 105.

Druce's List of British plants. (With Henry Hurd Rusby.) Torreya **8**: 113-116. May 19, 1908.

Grossulariaceae. (With Frederick Vernon Coville.) N. Am. Flora **22**: 193-225. June 12, 1908.

Connaraceae. N. Am. Flora **22**: 233-236. June 12, 1908.

The generic name Bucida. Bull. Torrey Club **35**: 303, 304, *f. 1*. July 1, 1908.

Exhibitions of specimens recently collected in Jamaica, with remarks. [Abstract.] Torreya **8**: 171. July 29, 1908.

Studies of West Indian plants—I. Bull. Torrey Club **35**: 337-345. July 30, 1908. Also as Contr. N. Y. Bot. Gard. no. 108.

Types of American grasses. Science II. **28**: 239, 240. August 21, 1908. (Review.)

Further exploration in Jamaica. Jour. N. Y. Bot. Gard. **9**: 163-172. October, 1908.

Beccari's American palms. Torreya **8**: 238-241. October 22, 1908. (Review.)

A new genus of Cactaceae. (With Joseph Nelson Rose.) Jour. N. Y. Bot. Gard. **9**: 185-188, *f. 31; pl. 48-52.* "November" [December] 1908.

Enriching soil by crimson clover. Jour. N. Y. Bot. Gard. **9**: 226-228. December, 1908.

1909

Studies of West Indian plants—II. Bull. Torrey Club **35**: 561-569. January 2, 1909. Also as Contr. N. Y. Bot. Gard. no. 118.

Urban's Symbolae antillanae. Torreya **8**: 293. January 6, 1909. (Review.)

Enclosing the Garden. Jour. N. Y. Bot. Gard. **10**: 1-3, *pl. 66.* January, 1909.

Darwin and botany. Pop. Sci. Mo. **74**: 355-360. "April" [March] 1909. Reprinted in Ann. N. Y. Acad. **19**: 28-33. July 31, 1909.

Report of the Secretary and Director-in-Chief for the year 1908. Bull. N. Y. Bot. Gard. **6**: 115-136. March 23. 1909.

Thompsonella, a new genus of Crassulaceae from Mexico. (With Joseph Nelson Rose.) Contr. U. S. Nat. Herb. **12**: 391, 392, *pl. 44, 45.* May 10, 1909.

Botanical exploration in the West Indies and Florida. Jour. N. Y. Bot. Gard. **10**: 99-114, *f. 17-26.* May, 1909.

The cactuses of the West Indies. [Abstract.] Torreya **9**: 126. June 1, 1909.

Scheuchzeriaceae. N. Am. Flora **17**: 41, 42. June 30, 1909.

The genus Cereus and its allies in North America. (With Joseph Nelson Rose.) Contr. U. S. Nat. Herb. **12**: 413-437, *pl. 61-76.* July 21, 1909.

Rhipsalis in the West Indies. Torreya **9**: 153-160, *f. 1-3.* August 3, 1909. Also as Contr. N. Y. Bot. Gard. no. 124.

The Botanical Garden in the Hudson-Fulton Celebration. Jour. N. Y. Bot. Gard. **10**: 171, 172. August, 1909. Reprinted (with changed title) in Torreya **9**: 189-191. September 27, 1909.

Need of additional funds. (With Charles Finney Cox and Addison Brown.) Jour. N. Y. Bot. Gard. **10**: 217-221. October, 1909.

Report on a visit to the Royal Gardens, Kew, and to the British Museum of Natural History, London, England. Jour. N. Y. Bot. Gard. **10**: 221-224. October, 1909.

1910

Death of Mr. Darius Ogden Mills, President of the Board of Managers. Jour. N. Y. Bot. Gard. **11**: 1. January, 1910. (Anonymous; authorship indicated in volume-index.)

The Bronx River at flood. Jour. N. Y. Bot. Gard. **11**: 2, 3. January, 1910.

Relations of botanical gardens to the public. Jour. N. Y. Bot. Gard. **11**: 25-30. "February" [March] 1910. Also in Science II. **31**: 641-644. April 29, 1910.

Report of the Secretary and Director-in-Chief for the year 1909. Bull. N. Y. Bot. Gard. **7**: 149-168. March 17, 1910.

Outlawed generic names. Jour. Bot. **48**: 110, 111. April 1, 1910.

Botanical exploration in Santa Clara, Cuba. Jour. N. Y. Bot. Gard. **11**: 109-117. May, 1910.

Recent botanical exploration in Cuba. [Abstract.] Torreya **10**: 134, 135. July 1, 1910.

Studies of West Indian Plants—III. Bull. Torrey Club **37**: 345-363. July 29, 1910. Also as Contr. N. Y. Bot. Gard. no. 135.

The Darius Ogden Mills Fund. Jour. N. Y. Bot. Gard. **11**: 225. October, 1910.

Botanical exploration in western Cuba. Jour. N. Y. Bot. Gard. **11**: 226-236, *f. 28-35*. October, 1910.

1911

The botany of some autumn flowers. [Abstract.] Jour. Hort. Soc. N. Y. **1**: 120, 121. January, 1911.

Parks, gardens, and playgrounds. In: Baskerville, Charles. Municipal chemistry: a series of thirty lectures by experts. 497-503, *f. 249-251*. 1911.

Rediscovery of Tillandsia Swartzii Baker. Torreya **11**: 31-33, *f. 1*. February 14, 1911.

Report of the Secretary and Director-in-Chief for the year 1910. Bull. N. Y. Bot. Gard. **7**: 271-293. March 16, 1911.

Botanical exploration in Cuba. Jour. N. Y. Bot. Gard. **12**: 89-95. May 31, 1911.

The botanical name of the wild sapodilla. Torreya **11**: 128, 129. June 19, 1911.

An undescribed Opuntia from Jamaica. Torreya **11**: 130. June 19, 1911.

Opuntia Tracyi sp. nov. Torreya **11**: 152. July 19, 1911.

John J. Crooke. Jour. N. Y. Bot. Gard. **12**: 160, 161. July, 1911.

A second species of Hernandia in Jamaica. Torreya **11**: 174. August 14, 1911.

Improvements along the western boundary of the Garden. Jour. N. Y. Bot. Gard. **12**: 174, 175. August, 1911.

Report on a visit to the Royal Gardens, Kew, England, and to the British Museum of Natural History. Jour. N. Y. Bot. Gard. **12**: 215-218. October, 1911.

1912

Undescribed species of Cuban cacti. (With Joseph Nelson Rose.) Torreya **12**: 13-16. January 22, 1912.

Studies of West Indian plants—IV. Bull. Torrey Club **39**: 1-14. February 10, 1912. Also as Contr. N. Y. Bot. Gard. no. 147.

The genus Hamelia Jacq. Torreya **12**: 30-32. February 15, 1912.

Charles Finney Cox. Jour. N. Y. Bot. Gard. **13**: 21-23, *portr.* February, 1912.

Report of the Secretary and Director-in-Chief for the year 1911. Bull. N. Y. Bot. Gard. **8**: 1-17. March 14, 1912.

Further botanical exploration in Cuba. Jour. N. Y. Bot. Gard. **13**: 69-76. May, 1912.

William Bayard Cutting. Jour. N. Y. Bot. Gard. **13**: 77, 78. May, 1912.

The preservation of our native plants. Craftsman **22**: 377-386. July, 1912. [Illust.]

Development of the path system of the Garden. Jour. N. Y. Bot. Gard. **13**: 124-126. August, 1912.

[The oldest tree in Manhattan. Abstract.] Torreya **12**: 275. November 10, 1912.

1913

Botanical exploration in Bermuda. Jour. N. Y. Bot. Gard. **13**: 189-194, *pl. 103-107*. February 4, 1913.

The Charles Finney Cox collection of Darwiniana. Jour. N. Y. Bot. Gard. **14**: 1, 2. February 13, 1913.

Report of the Secretary and Director-in-Chief for the year 1912. Bull. N. Y. Bot. Gard. **8**: 171-185. March 18, 1913.

Studies in Cactaceae.—I. (With Joseph Nelson Rose.) Contr. U. S. Nat. Herb. **16**: 239-242, *pl. 66-73*. April 10, 1913.

Cactus studies in the West Indies. Jour. N. Y. Bot. Gard. **14**: 99-109. June 3, 1913.

John Innes Kane. Jour. N. Y. Bot. Gard. **14**: 109. June 3, 1913.

Insurance of greenhouses. Jour. N. Y. Bot. Gard. **14**: 110. June 3, 1913.

The genus Epiphyllum and its allies. (With Joseph Nelson Rose.) Contr. U. S. Nat. Herb. **16**: 255-262, *pl. 78-84*. June 6, 1913.

An illustrated flora of the northern United States, Canada and the British possessions. (With Addison Brown.) Second edition. Vol. I. i-xxix, 1-680, *f. 1-1658*. Vol. II. i-iv, 1-735, *f. 1659-3329*. Vol. III. [i-iii] 1-637, *f. 3330-4666*. [June 7] 1913. Reprinted [April 7] 1936.

Addison Brown. Jour. N. Y. Bot. Gard. **14**: 119-121, *portr.* June, 1913.

John Pierpont Morgan. Jour. N. Y. Bot. Gard. **14**: 134, 135. July 26, 1913.

Four undescribed West Indian sedges. Torreya **13**: 215-217. September 2, 1913.

A destructive storm. Jour. N. Y. Bot. Gard. **14**: 160, 161. October 7, 1913.

Gardens of Bermuda. Jour. N. Y. Bot. Gard. **14**: 172-176. November 3, 1913.

Sclerocarpus africanus Jacq. in America. Torreya **13**: 273. December 30, 1913.

Rock's The indigenous trees of the Hawaiian Islands. Torreya **13**: 277, 278. December 30, 1913. (Review.)

1914

Studies of West Indian plants.—V. Bull. Torrey Club **41**: 1-24. February 27, 1914. Also as Contr. N. Y. Bot. Gard. no. 164.

Circular of the Endowment Fund committee. (With William Gilman Thompson.) Jour. N. Y. Bot. Gard. **15**: 23-28. March 10, 1914.

Report of the Secretary and Director-in-Chief for the year 1913. Bull. N. Y. Bot. Gard. **8**: 253-263. April 4, 1914.

Botanical exploration in Porto Rico and islands adjacent. Jour. N. Y. Bot. Gard. **15**: 95-103, *pl. 132-134*. June 6, 1914.

Charles Budd Robinson. Jour. N. Y. Bot. Gard. **15**: 106. June 6, 1914.

George Washington Vanderbilt. Jour. N. Y. Bot. Gard. **15**: 126, 127. June 26, 1914.

Clethraceae. N. Am. Flora **29**: 3-9. August 31, 1914.

The John Innes Kane Fund. Jour. N. Y. Bot. Gard. **15**: 175, 176. October 10, 1914.

On Erigeron pusillus Nutt. Torreya **14**: 197-199. October 27, 1914.

1915

Report of the Secretary and Director-in-Chief for the year 1914. Bull. N. Y. Bot. Gard. **9**: 1-17. March 31, 1915.

The vegetation of Mona Island. Ann. Missouri Bot. Gard. **2**: 33-58, *pl. 1, 2*. May 17, 1915. Also as Contr. N. Y. Bot Gard. no. 175.

Grant, by the city, of the use of additional land in Bronx Park. Jour. N. Y. Bot. Gard. **16**: 85-96, *2 maps*. June 12, 1915.

Further botanical exploration of Porto Rico. Jour. N. Y. Bot. Gard **16**: 103-112. July 5, 1915.

Studies of West Indian plants.—VI. Bull. Torrey Club **42**: 365-392. July 29, 1915. Also as Contr. N. Y. Bot. Gard. no. 179.

Permanent funds and endowment. Jour. N. Y. Bot. Gard. **16**: 123-130. August 7, 1915.

Thomas Hamlin Hubbard. Jour. N. Y. Bot. Gard. **16**: 146. August 7, 1915.

History of the New York Botanical Garden. 1-16. [September 6, 1915.]

John Francis Cowell. Jour. N. Y. Bot. Gard. **16**: 191-193. September 24, 1915.

Bequest of Jacob Langeloth. Jour. N. Y. Bot. Gard. **16**: 225. November 2, 1915.

Studies of West Indian plants.—VII. Bull. Torrey Club **42**: 487-517. November 5, 1915. Also as Contr. N. Y. Bot. Gard. no. 183.

The Mansion. Jour. N. Y. Bot. Gard. **16**: 231-233, *pl. 164*. November, 1915.

A Cuban journal of natural history. Jour. N. Y. Bot. Gard. **16**: 237, 238. November, 1915.

1916

Report of the Secretary and Director-in-Chief for the year 1915. Bull. N. Y. Bot. Gard. **9**: 85-106. March 20, 1916.

Cassia polyphylla. Many-leaved senna. Addisonia **1**: 3, 4 *pl. 2*. March 31, 1916.

Nopalea Auberi. Auber's nopal. Addisonia **1**: 19, 20, *pl. 10*. March 31, 1916.

The natural vegetation of the Isle of Pines, Cuba. Jour. N. Y. Bot. Gard. **17**: 64-71, *pl. 170*. June 22, 1916.

Exogonium microdactylum. Slender red exogonium. Addisonia **1**: 33, 34, *pl. 17*. June 30, 1916.

Opuntia macrorhiza. Large-rooted prickly pear. Addisonia **1**: 37, 38, *pl. 19*. June 30, 1916.

Bequest of Emil C. Bondy. Jour. N. Y. Bot. Gard. **17**: 87. July 14, 1916.

Nelson Smith. Jour. N. Y. Bot. Gard. **17**: 103, 104. August 5, 1916.

The vegetation of Anegada. Mem. N. Y. Bot. Gard. **6**: 565-580. "August 31" [September 8] 1916.

The rose garden plans. Jour. N. Y. Bot. Gard. **17**: 111-115, *pl. 175-177*. September 12, 1916.

The New York Botanical Garden and Columbia University. Columbia Univ. Quart. **18**: 352-359. September, 1916.

Sisyrinchium Bermudiana. Bermuda Iris. Addisonia **1**: 43, 44, *pl. 22*. September 30, 1916.

Anthurium grandifolium. Large-leaved tail-flower. Addisonia **1**: 53, 54, *pl. 27*. September 30, 1916.

A white pine planting. Jour. N. Y. Bot. Gard. **17**: 152-154. October 14, 1916.

Studies of West Indian plants.—VIII. Bull. Torrey Club **43**: 441-469. October 20, 1916. Also as Contr. N. Y. Bot. Gard. no. 192.

A "Convention Garden." Jour. N. Y. Bot. Gard. **17**: 172, 173. November 3, 1916.

Opuntia vulgaris. Tall South American prickly pear. Addisonia **1**: 75, 76, *pl. 38*. December 30, 1916.

Echeveria australis. Southern echeveria. Addisonia **1**: 79, 80, *pl. 40*. December 30, 1916.

1917

Studies of West Indian plants.—IX. Bull. Torrey Club **44**: 1-37. February 12, 1917. Also as Contr. N. Y. Bot. Gard. no. 195.

Further development of the New York Botanical Garden. Jour. N. Y. Bot. Gard. **18**: 29-31. February 27, 1917.

Peperomia obtusifolia. Blunt-leaved peperomia. Addisonia **2**: 19, 20, *pl. 50.* March 31, 1917.

Report of the Secretary and Director-in-Chief for the year 1916. Bull. N. Y. Bot. Gard. **9**: 293-311. April 10, 1917.

Instruction in gardening, in cooperation with the International Children's School Farm League. Jour. N. Y. Bot. Gard. **18**: 53-61, *pl. 192.* April 13, 1917.

Courses in gardening in cooperation with the International Children's School Farm League. Jour. N. Y. Bot. Gard. **18**: 95-98. June 11, 1917.

El genero Rynchospora Vahl, en Cuba. Mem. Soc. Cubana "Felipe Poey" **2**: 185-200. "September-December, 1916" [June, 1917]. Also as Contr. N. Y. Bot. Gard. no. 194.

Forests, hygiene and ethics. N. Y. Forestry **4**[2]: 24, 25, 32. July, 1917.

Selden's Everyman's garden every week. Torreya **14**: 128. July 17, 1917. (Review.)

Harrisia gracilis. Jamaica harrisia. Addisonia **2**: 41, 42, *pl. 61.* September 29, 1917.

Harrisia Martini. Martin's harrisia. Addisonia **2**: 55, 56, *pl. 68.* September 29, 1917.

Piaropus azureus. Light-blue water-hyacinth. Addisonia **2**: 67, 68, *pl. 74.* December 31, 1917.

1918

The relatives of catalpa trees in the West Indies. Jour. N. Y. Bot. Gard. **19**: 6-9, *pl. 209.* "January" [February] 1918.

Flora of Bermuda (illustrated). i-ix, 1-585, *frontisp., f. 1-519.* February 28, 1918.

An undescribed Scirpus from California. Torreya **18**: 36, 37, *f. 1.* March 8, 1918.

Aronia atropurpurea. Purple-fruited choke-berry. Addisonia **3**: 1, 2, *pl. 81.* March 30, 1918.

Opuntia lasiacantha. Slender white-spined prickly pear. Addisonia **3**: 19, 20, *pl. 90.* March 30, 1918.

First grant from the income of the Charles Budd Robinson Fund. Jour. N. Y. Bot. Gard. **19**: 47, 48. April 1, 1918.

Report of the Secretary and Director-in-Chief for the year 1917. Bull. N. Y. Bot. Gard. **9**: 403-433. April 30, 1918.

The Herbaceous Grounds. Jour. N. Y. Bot. Gard. **19**: 77-79. April 30, 1918.

John Adolph Shafer. Jour. N. Y. Bot. Gard. **19**: 97-99. May, 1918. Reprinted, in Spanish translation, in Mem. Soc. Cubana "Felipe Poey" **3**: 225-228. "1918" [January, 1919].

A red pine plantation. Jour. N. Y. Bot. Gard. **19**: 105, 106. May, 1918.

Spring inspection of grounds, buildings, and collections. Jour. N. Y. Bot. Gard. **19**: 106-108. May, 1918.

Torrey Botanical Club reminiscences. Mem. Torrey Club **17**: 24-28. June 10, 1918.

Aronia arbutifolia. Red-fruited choke-berry. Addisonia **3**: 33, *pl. 97*. June 29, 1918.

The flora of the American Virgin Islands. Brooklyn Bot. Gard. Mem. **1**: 19-118. July 6, 1918. Also as Contr. N. Y. Bot. Gard. no. 203.

The botany and plant products of northern South America. Science II. **48**: 156, 157. August 16, 1918. (Anonymous.) Reprinted: An investigation of the flora of northern South America. Bull. Pan. Am. Union **47**: 232-234. August, 1918. Reprinted in Jour. N. Y. Bot. Gard. **19**: 182-185. "August" [September] 1918.

The School Garden Shelter House given by Mrs. Frederick Ferris Thompson. Jour. N. Y. Bot. Gard. **19**: 179, 180, *pl. 215*. "August" [September] 1918.

James Alexander Scrymser. Jour. N. Y. Bot. Gard. **19**: 180, 181. "August" [September] 1918.

Opuntia Opuntia. Eastern prickly pear. Addisonia **3**: 49, 50, *pl. 50*. September 30, 1918.

Byron David Halsted. Jour. N. Y. Bot. Gard. **19**: 221. "September" [October] 1918.

1919

Dr. Henry Allen Gleason, appointed first assistant. Jour. N. Y. Bot. Gard. **20**: 39, 40. "January" [February] 1919.

Report of the Secretary and Director-in-Chief for the year 1918. Bull. N. Y. Bot. Gard. **10**: 1-24. May 12, 1919.

The Cactaceae. Descriptions and illustrations of plants of the Cactus family. (With Joseph Nelson Rose.) Volume I. i-vii, 1-236, *f. 1-302; pl. 1-36*. June 21, 1919. Carnegie Institution of Washington, Publication no. 248, volume I. Reprinted as a supplement to the Journal of the Cactus and Succulent Society of America, vols. **3-6** (1931-34).

A large tulip tree struck by lightning. Jour. N. Y. Bot. Gard. **20**: 160. August, 1919.

History of the Survey. N. Y. Acad. Sci. Survey Porto Rico **1**: 1-10. September 26, 1919.

Addisonia: its progress and publication. Jour. N. Y. Bot. Gard. **20**: 181, 182. "September" [October 7] 1919.

The Scientific Survey of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **20**: 220, 221. November, 1919.

1920

Flora of the District of Columbia. Torreya **19**: 244-246. (Review.)

The wild pimento of Jamaica. Jour. N. Y. Bot. Gard. **21**: 38, 39. "February" [April 9] 1920.

About Paulownia trees. Jour. N. Y. Bot. Gard. **21**: 72, 73. "April" [May] 1920.

The Bahama flora. (With Charles Frederick Millspaugh.) i-viii, 1-695. June 26, 1920.

Cephalanthus occidentalis. Button-bush. Addisonia **5**: 17, 18, *pl. 169*. June 30, 1920.

Report of the Secretary and Director-in-Chief for the year 1919. Bull. N. Y. Bot. Gard. **10**: 213-219. June 30, 1920.

A botanical expedition to Trinidad. Jour. N. Y. Bot. Gard. **21**: 101-118. "June" [July] 1920.

The Cactaceae. Descriptions and illustrations of plants of the Cactus family. (With Joseph Nelson Rose.) Volume II. i-vii, 1-239, *f. 1-305; pl. 1-40*. September 9, 1920. Carnegie Institution of Washington, Publication no. 248, volume II. Reprinted; pages 1-148 as a supplement to the Journal of the Cactus and Succulent Society of America, vols. **6-8** (1934-36), the remainder separately in March, 1937.

Descriptions of Cuban plants new to science. Mem. Torrey Club **16**: 57-118. September 13, 1920. Also as Contr. N. Y. Bot. Gard. no. 225.

Two new West Indian plants. Torreya **20**: 83, 84. September 20, 1920.

George W. Perkins. Jour. N. Y. Bot. Gard. **21**: 179. "September" [October 13] 1920.

Report by the Director-in-Chief upon a visit to botanical institutions in England. Jour. N. Y. Bot. Gard. **21**: 197-208. November, 1920.

1921

Investigation of the flora of northern South America. Science II. **53**: 29, 30. January 14, 1921.

William Harris. Jour. N. Y. Bot. Gard. **22**: 13, 14. "January" [February 12] 1921.

Francis Lynde Stetson. Jour. N. Y. Bot. Gard. **22**: 44, 45. "February" [March 12] 1921.

Fanny Bridgham Fund. Jour. N. Y. Bot. Gard. **22**: 45, 46. "February" [March 12] 1921.

The leafy spurge becoming a pest. Jour. N. Y. Bot. Gard. **22**: 73-75, *f. 1*. "April" 1921

Further botanical studies in Trinidad. Jour. N. Y. Bot. Gard. **22**: 93-102. "May" 1921.

Neoabbottia, a new cactus genus from Hispaniola. (With Joseph Nelson Rose.) Smithson. Misc. Coll. **729**: 1-6, *f. 1, 2; pl. 1-4*. June 15, 1921. Also as Smithson. Inst. Publ. no. 2651.

The Cacti of Trinidad. Bull. Dep. Agr. Trin. Tobago **19**: 81-87. [June] 1921.

Stewardson Brown. Jour. N. Y. Bot. Gard. **22**: 110-112. June, 1921.

Report of the Secretary and Director-in-Chief for the year 1920. Bull. N. Y. Bot. Gard. **10**: 307-322. September 10, 1921.

[Plant nomenclature: more suggestions.] Jour. Bot. **59**: 296, 297. October, 1921.

George Valentine Nash. Jour. N. Y. Bot. Gard. **22**: 145-147, *pl. 261 (portr.)*. "August" [October] 1921.

Lathyrus latifolius. Everlasting pea. Addisonia **6**: 35, 36, *pl. 210*. October 24, 1921.

Dr. Pennell's new position. Jour. N. Y. Bot. Gard. **22**: 171, 172. "September" [December 8] 1921.

1922

Studies of West Indian plants.—X. Bull. Torrey Club **48**: 327-343. February 28, 1922. Also as Contr. N. Y. Bot. Gard. no. 236.

Botanical investigations in Porto Rico. Jour. N. Y. Bot. Gard. **23**: 49-59. "April" [June] 1922.

Report of the Secretary and Director-in-Chief for the year 1921. Bull. N. Y. Bot. Gard. **12**: 1-15. July 6, 1922.

Notes on the plants collected by Mr. Bucher on Pico Turquino, Cuba. (With Percy Wilson.) Jour. N. Y. Bot. Gard. **23**: 91-95. "July" [August] 1922.

Two new genera of Cactaceae. (With Joseph Nelson Rose.) Bull. Torrey Club **49**: 251, 252. August 31, 1922.

Polystachya minuta. Polystachya. Addisonia **7**: 19, *pl. 234*. September 25, 1922.

Xylophylla Epiphyllanthus. Hardhead. Addisonia **7**: 31, *pl. 240*. September 25, 1922.

The Cactaceae. Descriptions and illustrations of plants of the Cactus family. (With Joseph Nelson Rose.) Volume III. i-vii, 1-255, *f. 1-250; pl. 1-24*. October 12, 1922. Carnegie Institution of Washington, Publication no. 248, volume III.

Crotalaria retusa. Large yellow-rattlebox. Addisonia **7**: 47, *pl. 248*. December 4, 1922.

1923

Studies of West Indian plants.—XI. Bull. Torrey Club **50**: 35-56. February 7, 1923. Also as Contr. N. Y. Bot. Gard. no. 238.

Three new plants of the family Rubiaceae from Trinidad. (With Paul Carpenter Standley.) Jour. Wash. Acad. **13**: 105-107. March 19, 1923.

Cyperaceae. (Text, except Carex.) In: Abrams, Le Roy. An illustrated flora of the Pacific states **1**: 255-281. 1923.

Report of the Secretary and Director-in-Chief for the year 1902. Bull. N. Y. Bot. Gard. **12**: 103-115. June 7, 1923.

Botanical exploration of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **24**: 93-99. "May" [June] 1923.

Preface [to the Botany of Porto Rico and the Virgin Islands.] N. Y. Acad. Sci. Surv. Porto Rico **5**: 1-5. August 10, 1923.

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (part). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **5**: 7-158. August 10, 1923.

An unrecorded weed in Bermuda. Torreya **23**: 67, 68. August, 1923.

Bignonia radicans. Trumpet-creeper. Addisonia **8**: 39, 40, *pl. 276*. November 10, 1923.

Phlebotaenia Cowellii. Violet-tree. Addisonia **8**: 47, 48, *pl. 280*. November 10, 1923.

The Cactaceae. Descriptions and illustrations of plants of the Cactus family. (With Joseph Nelson Rose.) Volume IV. i-vii, 1-318, *f. 1-263; pl. 1-37*. December 24, 1923. Carnegie Institution of Washington, Publication no. 248, volume IV. "Pages 1-80, text only, were distributed under date of October 9, 1923."

1924

Francis Alexander Schilling. Jour. N. Y. Bot. Gard. **24**: 283, 284. "December, 1923" [January, 1924].

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (continued). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **5**: 159-316. January 10, 1924.

An extraordinary December. Jour. N. Y. Bot. Gard. **25**: 15, 16. January, 1924.

Plants of the Galapagos Islands. Jour. N. Y. Bot. Gard. **25**: 10, 11. "January" [February] 1924.

Hamelia axillaris. Yellow hamelia. Addisonia **8**: 51, *pl. 282*. February 5, 1924.

Lagetta Lagetto. Lace-bark tree. Addisonia **8**: 61, *pl. 287*. February 5, 1924.

Studies of West Indian plants.—XII. Bull. Torrey Club **51**: 1-12. February 8, 1924. Also as Contr. N. Y. Bot. Gard. no. 252.

La vegetación de cayo Icacos. Revista Agr. Puerto Rico **12**: 91-96. February, 1924.

The Scientific Survey of Porto Rico and the Virgin Islands. (Estudios cientificos sobre Puerto Rico y las Islas Virgenes.) Revista Agr. Puerto Rico **12**: 109, 110. February, 1924.

Las arenas de las planicies de la costa norte de Puerto Rico. Revista Agr. Puerto Rico **12**: 157, 158. March, 1924.

Porto Rico coffee slump. Tea & Coffee Trade Jour. **46**: 653, 654. May, 1924.

Report of the Secretary and Director-in-Chief for the year 1923. Bull. N. Y. Bot. Gard. **12**: 181-193. May 28, 1924.

Descriptive flora of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **25**: 129-135. May, 1924.

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (continued). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **5**: 317-474. June 16, 1924.

A botanical expedition to extreme western Cuba. Jour. N. Y. Bot. Gard. **25**: 194, 195. July, 1924.

Summer work with irises. Jour. N. Y. Bot. Gard. **25**: 196, 197. July, 1924.

Acer rubrum. Red maple. Addisonia **9**: 19, 20, *pl. 298*. July 30, 1924.

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (continued). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **5**: 475-626. November 8, 1924.

Asterandra grandifolia. Tobillo. Addisonia **9**: 41, *pl. 309*. November 15, 1924.

1925

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (continued). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **6**: 1-158. January 14, 1925.

The pinetum, the collection of evergreen trees. Jour. N. Y. Bot. Gard. **26**: 1-3. "January" [February] 1925.

Resignation of Doctor Murrill. Jour. N. Y. Bot. Gard. **26**: 13. "January" [February] 1925.

El plantel del servicio forestal de Puerto Rico. Revista Agr. Puerto Rico **14**: 83, 84. February, 1925.

Botany and horticulture of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **26**: 97-102. May, 1925.

The Charles Patrick Daly and Maria Lydig Daly Fund. Jour. N. Y. Bot. Gard. **26**: 161. July [25], 1925.

Report of the Secretary and Director-in-Chief for the year 1924. Bull. N. Y. Bot. Gard. **13**: 7-17. July 30, 1925.

Barleria Prionitis. Prionitis. Addisonia **10**: 17, *pl. 329*. August 6, 1925.

Urena lobata. Cadillo. Addisonia **10**: 19, *pl. 330*. August 6, 1925.

Erythrina Poeppigiana. Bucare. Addisonia **10**: 21, *pl. 331*. August 6, 1925.

Byrsonima Horneana. Mrs. Horne's byrsonima. Addisonia **10**: 23, *pl. 332*. August 6, 1925.

Tabebuia haemantha. Roble colorado. Addisonia **10**: 25, *pl. 333*. August 6, 1925.

Barbieria pinnata. Enredadera. Addisonia **10**: 27, *pl. 334*. August 6, 1925.

Chamaecrista mirabilis. Porto Rico partridge-pea. Addisonia **10**: 29, *pl. 335*. August 6, 1925.

Distictis lactiflora. Liana fragrante. Addisonia **10**: 31, *pl. 336*. August 6, 1925.

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta (continued). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **6**: 159-316. August 31, 1925.

Third grant from income of the Charles Budd Robinson Memorial Fund. Jour. N. Y. Bot. Gard. **26**: 195, 196. September [30], 1925.

The American oaks. Jour. N. Y. Bot. Gard. **26**: 205. September [30], 1925. (Review.)

The tree-cactuses of the West Indies. (With Joseph Nelson Rose.) Jour. N. Y. Bot. Gard. **26**: 217-221. October, 1925. [Illust.]

1926

An attempt to aid the natural propagation of hemlocks. Jour. N. Y. Bot. Gard. **27**: 6-9. January [21], 1926.

Bequest of Helen C. Inslee. Jour. N. Y. Bot. Gard. **27**: 17, 18. January [21], 1926.

A dwarf plantation. Jour. N. Y. Bot. Gard. **27**: 25-29. February [10], 1926.

Tree-ferns in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 88-90, *f. 4*. April [16], 1926.

Further botanical investigation in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 97-102. May [27], 1926.

Report of the Secretary and Director-in-Chief for the year 1925. Bull. N. Y. Bot. Gard. **13**: 95-108. June 3, 1926.

Botany of Porto Rico and the Virgin Islands. Descriptive flora.—Spermatophyta, with appendix (concluded). (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **6**: 317-371. June 15, 1926.

Osmia borinquensis. Porto Rico osmia. Addisonia **11**: 9, *pl. 357*. June 30, 1926.

A portrait of Mrs. Daly. Jour. N. Y. Bot. Gard. **27**: 135. June [30]. 1926.

Doctor William E. Wheelock. Jour. N. Y. Bot. Gard. **27**: 186. August [7], 1926.

The swamp cypresses. Jour. N. Y. Bot. Gard. **27**: 205-207. September [27], 1926.

Fourth grant from the income of the Charles Budd Robinson Fund. Jour. N. Y. Bot. Gard. **27**: 234. October [15], 1926.

Studies of West Indian plants.—XIII. Bull. Torrey Club **53**: 457-471. October 30, 1926. Also as Contr. N. Y. Bot. Gard. no. 284.

The American species of Stipa. Torreya **26**: 93-95. October 30, 1926. (Review.)

The David Lydig Fund. Jour. N. Y. Bot. Gard. **27**: 251, 252. "November" [December 4] 1926.

Teedia lucida. Shining teedia. Addisonia **11**: 37, *pl. 371*. December 9, 1926.

1927

Ipomoea quinquefolia. Small white morning-glory. Addisonia **11**: 63, *pl. 384*. January 5, 1927.

The William R. Sands Fund. Jour. N. Y. Bot. Gard. **28**: 23. January [28], 1927.

The Henry Iden Fund. Jour. N. Y. Bot. Gard. **28**: 45, 46. "February" [March 3] 1927.

A portrait of Judge Charles P. Daly. Jour. N. Y. Bot. Gard. **28**: 46. "February" [March 3] 1927.

Studies of the mimosas. Jour. N. Y. Bot. Gard. **28**: 67, 68. March [16], 1927.

The Darius Ogden Mills Fund. Jour. N. Y. Bot. Gard. **28**: 68, 69. March [16], 1927.

The Addison Brown Fund. Jour. N. Y. Bot. Gard. **28**: 89, 90. April [13], 1927.

Trees of Coamo Springs Hotel. 1-14. April, 1927. Los arboles de los Baños de Coamo. 1-15. April, 1927.

The Maria De Witt Jesup Fund. Jour. N. Y. Bot. Gard. **28**: 119, 120. May [17], 1927.

Report of the Secretary and Director-in-Chief for the year 1926. Bull. N. Y. Bot. Gard. **13**: 181-190. June 8, 1927.

Further botanical studies in Porto Rico. Jour. N. Y. Bot. Gard. **28**: 125-131, *f. 1, 2*. June [10], 1927.

The Fanny Bridgham Fund. Jour. N. Y. Bot. Gard. **28**: 148, 149. June [10], 1927.

Sabinea punicea. Caracolillo. Addisonia **12**: 21, *pl. 395*. June 30, 1927.

Angelonia salicariaefolia. Angelon. Addisonia **12**: 23, 24, *pl. 396*. June 30, 1927.

Planting of young hemlocks in the Hemlock Grove. (With Barrington Moore.) Jour. N. Y. Bot. Gard. **28**: 172, 173. July [9], 1927.

Bequest of Dr. George Newton Best. Jour. N. Y. Bot. Gard. **28**: 173, 174. July [9], 1927.

Opening address [at the International conference on flower and fruit sterility, August 12-14, 1926]. Mem. Hort. Soc. N. Y. **3**: 1. July, 1927.

The Francis Lynd Stetson Fund. Jour. N. Y. Bot. Gard. **28**: 200. August [5], 1927.

Stahlia monosperma. Cobana negra. Addisonia **12**: 33, 34, *pl. 401*. October 28, 1927.

Exogonium arenarium. Cambustera. Addisonia **12**: 35, *pl. 402*. October 28, 1927.

Niopa peregrina. Cojobana. (With Joseph Nelson Rose.) Addisonia **12**: 37, *pl. 403*. October 28, 1927.

Erythrina Corallodendrum. Coral tree. Addisonia **12**: 39, *pl. 404*. October 28, 1927.

Chamaefistula antillana. Hediondilla. (With Joseph Nelson Rose.) Addisonia **12**: 41, *pl. 405*. October 28, 1927.

Canavali maritima. Bay bean. Addisonia **12**: 45, *pl. 407*. October 28, 1927.

The Iris Garden entrance and boundary fence adjoining. Jour. N. Y. Bot. Gard. **28**: 266, 267. November [10], 1927.

Charles Frederick Rand. Jour. N. Y. Bot. Gard. **28**: 302, 303. December [27], 1927.

1928

Doctor W. Gilman Thompson. Jour. N. Y. Bot. Gard. **29**: 13, 14. January [28], 1928.

Mimosaceae. (With Joseph Nelson Rose.) N. Am. Flora **23**: 1-76. February 11, 1928.

Resolutions relative to the services of Doctor Frederic S. Lee to the New York Botanical Garden. Jour. N. Y. Bot. Gard. **29**: 42, 43. February [16], 1928.

Forestry and agriculture in Porto Rico. Jour. N. Y. Bot. Gard. **29**: 101-104. May [12], 1928.

Report of the Secretary and Director-in-Chief for the year 1927. Bull. N. Y. Bot. Gard. **13**: 257-260. May 31, 1928.

The John Innes Kane Fund. Jour. N. Y. Bot. Gard. **29**: 210, 211. August [16], 1928.

Mimosaceae (continuatio). (With Joseph Nelson Rose.) N. Am. Flora **23**: 77-136. September 25, 1928.

Bequest of the Burgess collection of asters. Jour. N. Y. Bot. Gard. **29**: 267, 268. October [20], 1928. Reprinted in Torreya **28**: 100, 101. November 16, 1928.

The herbarium of Eugene A. Rau. Jour. N. Y. Bot. Gard. **29**: 284, 285. November [30], 1928.

Mimosaceae (conclusio). (With Joseph Nelson Rose.) N. Am. Flora **23**: 137-194. December 20, 1928.

Ipomoea polyanthes. Yellow morning-glory. Addisonia **13**: 49, *pl. 441*. December 31, 1928.

Jussiaea angustifolia. Yerba de clavo. Addisonia **13**: 51, *pl. 442*. December 31, 1928.

Tetrazygia elaeagnoides. Cenizo. Addisonia **13**: 53, *pl. 443*. December 31, 1928.

Chamaecrista Swartzii. Tamarindillo. Addisonia **13**: 55, *pl. 444*. December 31, 1928.

Columnea Tulae. Tibey parasitico. Addisonia **13**: 57, *pl. 445*. December 31, 1928.

Rubus rosaefolius. Mountain raspberry. Addisonia **13**: 59, *pl. 446*. December 31, 1928.

Volkameria aculeata. Prickly myrtle. Addisonia **13**: 61, *pl. 447*. December 31, 1928.

Pentarhaphia albiflora. Porto Rico pentarhaphia. Addisonia **13**: 63, *pl. 448*. December 31, 1928.

1929

[Botanical nomenclature.] Proc. Internat. Congr. Pl. Sci. Ithaca. 1569, 1570. [April] 1929.

Further studies in Porto Rico. Jour. N. Y. Bot. Gard. **30**: 101-105. May [14], 1929.

Report of the Secretary and Director-in-Chief for the year 1928. Bull. N. Y. Bot. Gard. **13**: 351-354. May 31, 1929.

The shrub yellow-root. Jour. N. Y. Bot. Gard. **30**: 265-269, *f. 1*. November [14], 1929.

Pseudocopaiva Britton & Wilson, gen. nov. (With Percy Wilson.) Trop. Woods **20**: 28. December 1, 1929.

1930

The planting of a Stahlia on Arbor Day in Porto Rico. Jour. N. Y. Bot. Gard. **31**: 45-47. "February" [March 13] 1930.

The native Cactaceae of Porto Rico and the Virgin Islands. Jour. Cact. Succ. Soc. Am. **1**: 226-231. June, 1930.

Scientific Survey of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **31**: 161-167. July [21], 1930.

Texas cacti. Jour. Cact. Succ. Soc. Am. **2**: 285, 286. August, 1930. (Review.)

Scientific survey of Porto Rico and the Virgin Islands. Rev. Obr. Publ. Puerto Rico **7**: 242-245, *map*. September, 1930.

The cacti of Cuzco. Jour. Cact. Succ. Soc. Am. **2**: 308. September, 1930. (Review.)

Foreword. In: Houghton, Arthur Duvernoix. The cactus book. vii, viii. October, 1930.

Sabinea florida. Watapama. Addisonia **15**: 33, 34, *pl. 497*. October 25, 1930.

Corynella paucifolia. Retama. Addisonia **15**: 35, 36, *pl. 498*. October 25, 1930.

Jacquemontia subsalina. Subsaline jacquemontia. Addisonia **15**: 37, *pl. 499*. October 25, 1930.

Proustia Krugiana. Consul Krug's proustia. Addisonia **15**: 39, *pl. 500*. October 25, 1930.

Cestrum laurifolium. Galan del monte. Addisonia **15**: 41, *pl. 501*. October 25, 1930.

Acnistus arborescens. Gallinero. Addisonia **15**: 43, *pl. 502*. October 25, 1930.

Anoda acerifolia. Violeta. Addisonia **15**: 45, *pl. 503*. October 25, 1930.

Mentzelia aspera. Pegadora. Addisonia **15**: 47, *pl. 504*. October 25, 1930.

Krameriaceae. N. Am. Flora **23**: 195-200. November 18, 1930.

Caesalpiniaceae. (With Joseph Nelson Rose.) N. Am. Flora **23**: 201-268. November 18, 1930.

Note on Consolea corallicola Small. Jour. Cact. Succ. Soc. Am. **2**: 347, 348. November, 1930. [Illust.]

Caesalpiniaceae (conclusio). (With Joseph Nelson Rose.) N. Am. Flora **23**: 269-349. December 6, 1930.

Botany of Porto Rico and the Virgin Islands. Supplement to the descriptive flora—Spermatophyta. Bibliography—Spermatophyta and Pteridophyta. Index to Volume V and VI. (With Percy Wilson.) N. Y. Acad. Sci. Surv. Porto Rico **6**: 523-663. December 19, 1930.

1931

Note on Pilocereus Straussii. Jour. Cactus Soc. Am. **2**: 397. January, 1931.

Notes on Byrnesia Weinbergii. Jour. Cact. Succ. Soc. Am. **2**: 414. February, 1931.

The Cactaceae of Tehuacan. Jour. Cact. Succ. Soc. Am. **2**: 422. March, 1931. (Review.)

Additions to knowledge of Mexican Cactaceae. Jour. Cact. Succ. Soc. Am. **3**: 22. August, 1931. (Review.)

Recent scientific observations in Porto Rico. Jour. N. Y. Bot. Gard. **32**: 185-193. August [21], 1931.

Cyperaceae [of the Tyler-Duida Expedition]. Bull. Torrey Club **58**: 317, 318. November 21, 1931.

Caesalpiniaceae [of the Tyler-Duida Expedition]. Bull. Torrey Club **58**: 371, 372. December 11, 1931.

1932

Symplocos martinicensis. Aceituna blanca. Addisonia **17**: 1, *pl. 545*. May 21, 1932.

Brunfelsia americana. Aguacero. Addisonia **17**: 3, *pl. 546*. May 21, 1932.

Ghinia spinosa. Cardero. Addisonia **17**: 5, *pl. 547*. May 21, 1932.

Phthirusa caribaea. Hicaquillo. Addisonia **17**: 7, *pl. 548*. May 21, 1932.

Exogonium solanifolium. Cambustera de costa. Addisonia **17**: 9, *pl. 549*. May 21, 1932.

Stegnosperma halimifolia. Stegnosperma. Addisonia **17**: 11, *pl. 550*. May 21, 1932.

Portulaca poliosperma. Sand portulaca. Addisonia **17**: 13, 14, *pl. 551*. May 21, 1932.

Osmia geraniifolia. Geranium-leaved osmia. Addisonia **17**: 15, *pl. 552*. May 21, 1932.

The Alwin Berger succulent herbarium. Jour. N. Y. Bot. Gard. **33**: 196. "September" [October 4] 1932. Reprinted in Jour. Cact. Succ. Soc. Am. **4**: 290. December, 1932.

The eastern local distribution of Lemaireocereus Hystrix. Jour. Cact. Succ. Soc. Am. **4**: 285. November, 1932. [Illust.]

The flowers of Opuntia Hanburyana Weber. Jour. Cact. Succ. Soc. Am. **4**: 297, *f. 1-6.* December, 1932.

1933

An unrecognized species of cactus. Jour. Cactus Succ. Soc. Am. **4**: 355. "April" [May] 1933.

Arthur Hollick. Jour. N. Y. Bot. Gard. **34**: 121-124, *portr.* June [16], 1933.

John H. Finley, Foreman Gardener. Jour. N. Y. Bot. Gard. **34**: 148. July [14], 1933.

An undescribed cactus of Culebra Island, Puerto Rico. Jour. Cactus Soc. Am. **5**: 469. November, 1933.

New species of Colombian Mimosaceae and Caesalpiniaceae. (With Ellsworth Paine Killip.) Phytologia **1**: 23, 24. December, 1933.

1934

Record of germination of seeds of the violet tree or hueso (Phlebotaenia Cowellii) in the spring of 1933, and other notes on this tree. Agr. Notes Porto Rico Exp. Sta. 66: 1, 2. March, 1934.

1936

Mimosaceae and Caesalpiniaceae of Colombia. (With Ellsworth Paine Killip.) Ann. N. Y. Acad. **35**: 101-208, *pl. 1, 2.* April 1, 1936.

William Morton Wheeler

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OF

WILLIAM MORTON WHEELER

1865–1937

BY

GEORGE HOWARD PARKER

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WILLIAM MORTON WHEELER

1865–1937

BY GEORGE HOWARD PARKER

William Morton Wheeler, son of Julius Morton Wheeler and Caroline Georgiana (Anderson) Wheeler, was born in Milwaukee, Wisconsin, March 19, 1865. Of his very early childhood little or nothing is recorded, but of his school days and early life Wheeler has left a sketch from his own pen that carries with it all the freshness and energy of youth. This sketch is contained in an article published in "Natural History" (1927) and entitled "Carl Akeley's Early Work and Environment." Akeley became one of Wheeler's early and most intimate friends and Wheeler's appreciation of him contains so much that is autobiographical that it would be difficult to do better in recording Wheeler's own youthful experiences than to cite directly from this source.

Wheeler wrote: "I was born in 1865 in Milwaukee and lived there till I was nearly nineteen. The cerevisiacal fame which that city enjoyed in those preprohibition days unfortunately quite eclipsed the fame of its temperate and highly intellectual German population and excellent school system.

"Owing to my persistently bad behavior soon after I entered the public school my father transferred me to a German academy founded by Peter Engelmann, an able pedagogue who had immigrated to the Middle West in 1848. The school had a deserved reputation for extreme severity of discipline. To have annoyed one of the burly Ph.D.'s, who acted as my instructors, as I had annoyed the demure little schoolmarms in the ward school, would probably have meant maiming for life at his hands or flaying alive by the huge Jewish director, Dr. Isidore Keller, 'curled and oiled like an Assyrian bull'.

"After completing the courses in the academy, I attended a German normal school which somehow had come to be appended to the institution. A few weeks before my father's death in January, 1884, an incident occurred which was to influence my whole subsequent life and indirectly Carl Akeley's. Prof. H. A. Ward, proprietor of Ward's Natural Science Establishment in Rochester, New York, which was not so much a museum as a museum factory, learned that there was to be an exposition in Milwaukee in the fall of 1883 and that the local German

academy, which I had attended, possessed a small museum. He decided, therefore, to bring a collection of stuffed and skeletonized mammals, birds, and reptiles, and an attractive series of marine invertebrates to the exposition, and to persuade the city fathers to purchase the lot, combine it with the academy's collection, and thus lay the foundation for a free municipal museum of natural history. I had haunted the old academy museum since childhood and knew every specimen in it. Indeed, Dr. H. Dorner, my instructor in natural science, had often permitted me to act as his assistant. Of course, I was on hand when Professor Ward's boxes arrived, and I still remember the delightful thrill with which I gazed on the entrancing specimens that seemed to have come from some other planet. I at once volunteered to spend my nights in helping Professor Ward unpack and install the specimens, and I worked as only an enthusiastic youth can work. He seems to have been duly impressed by my industry, because he offered me a job in his establishment. I was quite carried away with the prospect of passing my days among the wonderful beasts in Rochester. Not the least of Professor Ward's attainments were his uncanny insight into human nature and his grim business and scientific acumen. He offered me the princely salary of nine dollars a week, six of which were to be deducted for board and lodging in his own house.

"I entered Ward's Establishment February 7, 1884. My duties consisted in identifying, with the aid of a fair library, and listing birds and mammals. Later I was made a foreman and devoted most of my time to identifying and arranging the collections of shells, echinoderms, and sponges, and preparing catalogues and price lists of them for publication. Such is the present state of conchology that my shell-catalogue is still used by collectors. At this time Akeley entered the establishment as a budding taxidermist, and for once Professor Ward's estimate of human nature seems to have been at fault, for as Akeley informs us in *In Brightest Africa* he was given a salary of $3.50 a week, without board and lodging. He attached himself to William Critchley, a young and enthusiastic artisan, with the voice and physique of an Italian opera tenor, who had attained the highest proficiency in the taxidermic methods of the time, but did not seem to give promise of advancing the art. In the course of a year Akeley had more than mastered all that Critchley could teach him, and was longing for wider opportunities than could be offered by an establishment, which, after all, was neither an art school nor a scientific laboratory, but a business venture. But even so, there is reason to believe that its stand-

ards of workmanship were higher than in any of the museums that had grown up in various parts of the country.

"The relations between Akeley and myself soon ripened into a warm friendship. We were nearly of the same physical age, but I was the younger and more unsettled mentally, for he had been reared by sturdy parents on a quiet farm and I had been brought up in a bustling city with a superheated atmosphere of German Kultur. He was very strong and healthy, had an inexhaustible capacity for work, a great fund of quiet humor, and a thoroughly manly disposition. He seemed to have been born with unusual taste and discrimination and an intuition which could dispense with mere book-learning. Of all the men I have known—and my profession has brought me in contact with a great many—he seems to me to have had the greatest range of innate ability. Although he later became an unusual sculptor, inventor, and explorer, he would probably have been equally successful in any other career.

"In the course of time our relations settled into those of affectionate older and younger brothers. I cannot recall that we were ever even on the verge of a quarrel, and this must have been due to Akeley's self-restraint and sympathetic tolerance, because I was often irritable and unwell in those days. Owing to the fact that we did not work in the same building, our companionship was largely limited to evenings and Sundays. As I read the diaries of 1884 and 1885 I marvel at the multiplicity of our youthful interests and occupations. I cite a few passages to illustrate how we spent some of our spare hours.

'Monday, Jan. 6, 1885.* Worked on the glossary for the shell-catalogue all day. In the evening went with Carl to hear Bob Ingersoll in his lecture "Which Way?" We were much pleased with him and his wit. The lecture cleared from my mind a host of prejudices against this man who is after all a *real he man*. Weather cold.'

'Sunday, Feb. 15, 1885. Rose late. Took a walk with Carl and then went to church (Unitarian) with him to hear Doctor Mann give a magnificent sermon on the text "Out of Egypt will I call my son." Worked on algebra and read Virgil after dinner. Then walked down West Ave. with Fritz Mueller (a former schoolmate whom I was coaching in Latin for entrance to Johns Hopkins. He was the living image of the famous physiologist Johannes Mueller and probably belonged to the same family). Tired on my return. Fritz read to me Jean Paul Friedrich Richter's "Kampaner Thal." '

* In this and other starred quotations the day of the week and the day of the month do not coincide for the year 1885; as approximations they are sufficient.

'Thursday, Feb. 26, 1885. Worked on the shell-catalogue more diligently than on previous days, but am still low-spirited. In the evening read the conclusion of the Aeneid and some of Zeller's "Deutches Reich" with Louis Akeley (Carl's brother who was attending the University of Rochester and whom I was coaching in German). To bed at quarter of twelve.'

'Monday, March 23, 1885. Worked all day on the foetal Marsupials: kangeroos, koalas, opossums, etc. Labelled all the foetuses and pouches. In the evening walked with Fritz and on returning read with him about 100 lines of the third book of the Aeneid. The evening ended with an acrimonious dispute and I went to bed in high dudgeon.'

'Thursday, March 24, 1885.* Worked all day in Prevotel's shop, changing and labelling the alcoholic fishes. In the evening attended the meeting of the Geological Section of the Rochester Academy of Sciences. Mr. Preston read to us about a quarter of Geikie's "Primer of Geology." After the meeting walked with Mr. Shelley Crump (an amateur conchologist and prosperous grocer of Pittsford, New York, to whom I had become greatly attached). To bed at eleven.'

And this is an account of a week-end with Mr. Crump:

'Sunday, May 23, 1885.* From 10 to 12 worked with Professor Ward in the shell-house, labelling Echini—the last time I saw him (for many years). In the afternoon Mr. Crump and his friend, Doctor Dunning, called on me. I walked with them to Brighton and thence took the train to Pittsford. We read together some recent papers on Pasteur by Tyndall and others and then walked along the Erie Canal bank where I collected two species of Valvata.'

'Monday, May 24, 1885.* Rose late. Read some of Burrough's 'Wake Robin' before breakfast. Then conversed with Dr. Dunning on Shakespeare's 'Sonnets' (Dr. D. was blind and with the aid of his wife was preparing a volume on the sonnets). At 9.20 took the train for Rochester and went to work in the shell-house finishing the family Nassidae and part of the Volutidae.'

'Tuesday, June 23, 1885. In the morning read Bluntschli with Louis Akeley. In the afternoon went with Carl, Will Critchley, and Mr. Crump to see the tobacconist Kimball's beautiful collection of orchids. Succeeded in making a Catasetum discharge its pollinia! In the evening read Bluntschli again after having seen Mr. Crump off on the West Shore train. Returned much fatigued. My eyes begin to pain me.'

"Of active, industrious young men there seem to be two types. One of them accepts a given environment and is not only

satisfied with its routine and constantly recurring human contacts but prefers it to any change. These young men are apt to marry early and to become the conservative and contented *fond* of our society. Those of the other type, probably endowed with a more unstable if not more vivid imagination and with a peculiar defence reaction, or subconscious dread of being owned by people and things, soon exhaust the possibilities of their medium, like fungi that burn out their substratum, and become dissatisfied and restless till they can implant themselves in fresh conditions of growth. Akeley and I were of this latter type, and by the spring of 1885 had decided to leave the establishment at the earliest opportunity. I departed June 29 and returned to Milwaukee.

"Soon after my return to Milwaukee my old friend, Dr. George W. Peckham, who had long been making important contributions to arachnology and was beginning his well-known studies on the behavior of the solitary and social wasps, persuaded me to take a position as teacher of German and physiology in the high school of which he was principal. Peckham was a very learned and charming man, deeply steeped in the evolutionary literature of the time and keenly alive to the possibilities of the new morphology that had been inaugurated by Huxley in England and a host of remarkable investigators in the laboratories of the German universities. Every year he most conscientiously read, as a devout priest might read his breviary, Darwin's *Origin* and *Animals and Plants under Domestication*. We became very intimate, and I find from my diaries that for some years I regularly spent my Sunday mornings in his house drawing the palpi and epigyna of spiders to illustrate the papers which he wrote in collaboration with his equally gifted and charming wife. I was privileged to collaborate with them in one paper (on the Lyssomanae) and to help them during the summers in their field work on the wasps at Pine Lake, Wisconsin. Under Peckham's management the biological work of the Milwaukee high school was carried far beyond that of any similar institution in the country. There were classes in embryology with Foster as a text. We possessed a Jung microtome and the paraphernalia for staining sections and demonstrating the development of the chick, and, of course, the classes in physiology were required to master Huxley and Martin. While at Ward's I had purchased Carnoy's *Biologie Cellulaire* and had imbibed from it an intense but rather ineffectual interest in cytology. Then most fortunately, Mr. E. P. Allis established his 'Lake Laboratory' in his residence near the high school and appointed Prof. C. O. Whitman as its director and Dr. William Patten, Dr. Howard Ayres, and Mr.

A. C. Eycleshymer as assistants. These gentlemen were, of course, actively spreading the gospel of the new morphology. Doctor Patten, only four years my senior and fresh from Leuckart's laboratory in Leipzig, taught me the latest embryological technique and suggested that I take up the embryology of *Blatta* and other insects. I find that I devoted nearly all my spare time to this work till 1890.

"In the meantime the Milwaukee Public Museum had been established according to the plan suggested by Professor Ward, and I saw an opening for Akeley as its taxidermist. I persuaded him to come to Milwaukee and live with me. He arrived November 8, 1886, and although he was not officially appointed to the institution till November 20, 1888, he was given a certain amount of its work. We converted a barn on my mother's place into a shop and here he worked at least during the evenings for several years. I was made custodian of the Museum, September 19, 1887, and held the position till August 29, 1890. By that time my association with Peckham, Whitman, and Patten had converted me into a hard-boiled morphologist, and I was induced by Whitman to accept a fellowship at Clark University, where he had become professor of zoology a year earlier. Till October 1, 1890, when I left Milwaukee for good, Akeley and I had spent so many happy hours together that the parting was painful. After leaving the high school I had fitted up a laboratory in the house and when my eyes grew weary with the microscope I repaired to his shop and read to him while he worked or more rarely he read to me. My diary mentions the volumes we read and I wonder at Akeley's patience and apparent pleasure in listening to Bryce's *American Commonwealth,* translations of Aeschylus, Max Nordau, and similar highbrow stuff. I patiently read a whole small library for at that time I had serious conscientious objections to beginning a book without reading its every word. Perhaps Akeley really heard only occasional important fragments and had found that he could carry on his own trains of inventive thought better when we were together and I was making a continual but not too disturbing noise."

Such is the glimpse that we can gain into Wheeler's early life as recorded by himself. During this period he had graduated from the German-American Normal College (1884), had worked for the greater part of a year as an assistant in Ward's Natural Science Establishment (1884-1885), had taught German and physiology in the Milwaukee High School (1885-1887), and had served as Custodian of the newly established Milwaukee Public Museum (1887-1890), an amazing degree of activity

for one just turned twenty-five years of age. Looked on as a preparation for future work this body of training and experience could scarcely have been excelled. Devoid of the restraints of academic surroundings and free to expand by normal means, Wheeler's youthful growth was one of unexampled progress. Well grounded in languages both ancient and modern, conversant with the historical past, and filled with enthusiasm for biology and its future, he was ready for his life-long work in productive scholarship. Exceptional as this outlook was, it is remarkable how naturally and simply it was attained. Free of the cumbersome conventions of an educational system, Wheeler moved directly and without embarrassment to the end in view.

The formal beginnings of scholarly output from any research worker are as a rule shown in his publications. In this Wheeler made an early start. Probably his first published article was the catalogue of mollusks and brachiopods already referred to in his diary and prepared for Ward's Natural Science Establishment. This catalogue, which was by no means a mere price-list of the materials available at Ward's, was used for many years by conchologists, both amateur and professional, in the classification and arrangement of their specimens. It was at once trustworthy, compact, and inexpensive. It was put forth anonymously and without date, like a picture by an Italian primitive, but those who used it knew its author. On his return from Rochester to Milwaukee, Wheeler prepared a list of the trees of his native city (1885) and the next year he published his first entomological paper, an account of the beetles from the lake beaches of Milwaukee County. Thus began that incomparable series of scientific publications that reached without interruption from this early period to the time of his death.

By a strange but fortunate coincidence, Milwaukee in the later years of Wheeler's residence there became a center of unusual zoological activity. The director of the Lake Laboratory, Dr. Whitman, and two of his assistants had recently returned from study in the European zoological centers and were filled with enthusiasm for the new morphology, its fascinating problems, and how to attack them. In this company, Wheeler found himself a welcome guest and soon became, to use his own ex-

pression, "a hard-boiled morphologist." At about this time, 1887, Whitman, with the cooperation of E. P. Allis, Jr., launched the new *Journal of Morphology* and the next year, 1888, he undertook the establishment of the Marine Biological Laboratory at Woods Hole, Massachusetts. To the small circle of workers in Milwaukee these days must have been days full of feverish excitement. Wheeler once related that while he and Patten were walking from the Lake Laboratory, Patten was suddenly taken with an idea about the ancestry of the vertebrates and, as was characteristic of him, elaborated the whole matter on the spot and at great length. This idea, that vertebrates were derived from arachnid ancestors, subsequently occupied Patten during the greater part of his life, but in Milwaukee it struck him all in a moment. It was Patten also who instigated in Wheeler the desire to study insect embryology and suggested to him that he take up the investigation of the development of the common cockroach. This subject occupied much of Wheeler's spare time in his later years at Milwaukee where its investigation was carried on by him in part at the Milwaukee High School and in part at the Lake Laboratory. In 1889 it appeared under the title of "The Embryology of Blatta germanica and Doryphora decemlineata" in the third volume of the *Journal of Morphology*. This study was followed in 1893, after Wheeler had gone to Clark University, by his "Contribution to Insect Embryology," also published in Whitman's new journal. These two papers have long been recognized as classics in their fields of research. The first, done in Milwaukee, is a tribute to the intense zoological activities of the place and particularly of the Lake Laboratory. Here researches in other directions and by other workers were progressing with prodigious strides, and into this whirl of scientific activity Wheeler threw himself without reserve.

But the Lake Laboratory was not to maintain itself long. It soon lost its first director, Dr. Whitman, after which it steadily declined. Other institutions were arising. Clark University had been founded for research in Worcester, Massachusetts, and distinguished scholars in many fields were being called to it. The eminent psychologist, Dr. G. Stanley Hall, was its new

president and through him Dr. Whitman was invited to be head of its department of biology. Whitman accepted the offer and was followed by Wheeler who in 1890 became Fellow and Assistant in Morphology at Clark. Here new associations were to be made, and Wheeler found himself on terms of growing intimacy with Dr. Sho Watase, the promising Japanese zoologist direct from the biological laboratories of Johns Hopkins University. Dr. Jacques Loeb, the brilliant young general-physiologist on a brief visit to Clark also made Wheeler's acquaintance. Both these men particularly in consequence of their later association with Wheeler in Chicago became his life-long friends.

During his sojourn at Clark, Wheeler continued his work on insects and published in this period some ten papers almost all of which were entomological in substance. In 1892 he presented himself as a candidate for the degree of Ph.D. on the basis of his work on insect embryology and Clark University granted him that degree.

But the situation at Clark was not a happy one. The members of its faculty were newly brought together and, never having been associated before, their relations were not without friction. As a research university, Clark did not especially encourage the coming of a body of students and consequently the lack of flow through its gates of the young life so essential to the welfare of all such institutions made itself felt, especially among certain of the older men. An atmosphere of discontent arose and openings in other universities were sought by those who only one or two years before had looked upon Clark as a scholar's Utopia. Dr. Whitman received a call from the newly opened University of Chicago. This he accepted and carried with him to this new academic center Dr. Watase and Dr. Wheeler. Thus Wheeler in 1892 became Instructor in Embryology at Chicago under Dr. Whitman. This post he held till 1897 when he was advanced to Assistant Professor in his chosen subject.

As a preparation for his new duties in Chicago, Wheeler spent the academic year of 1893-1894 in Europe. He first went to the Zoological Institute at the University of Würzburg whose new director, Professor T. Boveri, had just succeeded the late

Professor C. Semper, the founder of the new Institute. Here Wheeler made first-hand acquaintance with student life in a German university. Part of the winter of 1893-1894 he spent at the Naples Zoological Station whose genial director, Dr. Anton Dohrn, did much to advance his interest in marine zoology. At the Naples Station, Wheeler occupied the table supported by the Smithsonian Institution. Though an inland man by both birth and training Wheeler's first acquaintance with marine life was not at Naples, for he had already spent, while in America, the summers of 1891 and 1892 at the Marine Biological Laboratory at Woods Hole. But the fauna at Naples was a great novelty to him and an unending stimulus to research. Here he began his studies on the sex life of Myzostoma, a subject which he carried with him to the Institut Zoologique at Liége, Belgium, where he worked in the laboratory of Professor E. Van Beneden. Subsequently his monograph on Myzostoma was published by Van Beneden in the *Archives de Biologie* (1897).

On his return to America in 1894 Wheeler settled down in Chicago to five years of active university work as a teacher of embryology. Of the score or more papers published by him during this period about half of them have to do with insects showing the predominantly entomological trend of his interest, a trend that dated back to 1885 when in Milwaukee he met Dr. and Mrs. George W. Peckham. These two ardent and accomplished entomologists fostered, as the extracts from Wheeler's diary show, his growing interests in the insect world.

In Chicago, Wheeler met, and on June 28, 1898, married Miss Dora Bay Emerson of Rockford, Illinois, a woman of great personal charm and delightful presence, who in the years that followed made his household a hospitable center for friends and for distinguished visitors from all quarters of the globe.

Wheeler's scientific interests though strongly entomological were never limited to this field. The fact that in Chicago he taught embryology for over five years is sufficient evidence of this. It is therefore not surprising when in 1899 he was offered the Professorship in Zoology with its wider outlook at the University of Texas, Austin, Texas, he should resign his position in Chicago and move to this southern institution. Here he remained

for about four years in what might be called an almost pioneer academic atmosphere, for the University of Texas combined at once persons of great refinement as well as those of a more rugged temperament. His publications over this period number about two score and are remarkable for the fact that almost three-fourths of them deal with ants, the group of insects which during the remainder of his days were to claim his chief attention. His other publications show an increasing breadth of scientific interest, for beside reviews in such diverse directions as Korschelt and Heider's "Textbook of Embryology" and Calkin's "Protozoa" he has much to say on the social life of ants, their mixed colonies, myrmecophiles, and the never-ending problem of organic evolution.

During this period students in his chosen field began to resort to him. C. T. Brues and A. L. Melander, both now well known entomologists, sought to study under Wheeler in Chicago, but having found him removed to the University of Texas, they made their way to Austin and spent several years there in his laboratory. Thus began an influx of younger, capable men who as pupils and scientific associates sought him out for longer or shorter periods of study and research under his guidance. During Wheeler's stay in Texas his two children were born, not, however, in Austin, but in Rockford, Illinois, the home town of his wife.

Rather overfed with the duties of teaching and of laboratory management, Wheeler was induced in 1903 to resign his position as Professor of Zoology in Texas and to accept the Curatorship of Invertebrate Zoology in the American Museum of Natural History in New York City. Here it fell to him to organize and arrange the Hall of Invertebrate Life and this beautiful exhibit with its remarkable display of specimens and its many truly wonderful glass models stands as a token of Wheeler's endless industry and good management. Behind the scenes he was occupied with work on the insects and, as his four score publications from this period show, his attention was devoted almost exclusively to the ants. His work on these insects was in no sense restricted, for he was active not only in the description of new species and in their classification but in their structure, func-

tions, distribution, habits and above all in their social relations and ecology. At no time during his earlier life had Wheeler so concentrated his activities on a special group of related problems as he did during his five years as Curator at the American Museum and at no time before had the results of his work been more brilliant and permanently enduring. The most conspicuous product of this period was the volume he contributed to the Columbia University Biological Series entitled "Ants: Their Structure, Development and Behavior." On the pages of this book are epitomized the intense work of a decade by one whose genius was at its full height.

But once a teacher always a teacher, and after five years of museum work, Wheeler felt the call of the lecture table, the laboratory, and the daily contact with aspiring young workers all of which together form an atmosphere, the nearest approach to a scientific scholar's ideal. Consequently when a call came to him to become Professor of Economic Entomology at the Bussey Institution of Harvard University he accepted it without reluctance and entered a new academic environment in which he was to remain longest of all. Here he worked almost thirty years, for in one capacity or another he was intimately associated with Harvard University from 1908 till his death in 1937. This final period in Wheeler's career must be looked upon as the one in which the great promise of his early days achieved complete realization and his genius ripened to full maturity. Over about two thirds of this period (1908-1926) he was Professor of Economic Entomology, a title which indicated the general trend of the Bussey Institution, but this title he preferred to change, and from 1926 to 1934 he served under the more general and certainly the more appropriate designation of Professor of Entomology. In 1934 he was made Professor of Entomology Emeritus. From 1915 to 1929 he was Dean of the Faculty of the Bussey Institution and from 1929 to 1937 he was Associate Curator of Insects in the Museum of Comparative Zoology. During the whole of the period of his association with Harvard University in recognition of his services at the American Museum of Natural History he was a Research Associate of that Museum.

Wheeler's entrance into the Bussey Institution came directly

after the reorganization of that body and he found himself associated there with a growing group of research workers in biology. At that time the Bussey Institution was one of the Graduate Schools of Applied Science under the deanship of Professor Wallace C. Sabine. On the dissolution of this body in 1914, the Bussey acquired a faculty of its own of which Wheeler was made dean (1915). Meanwhile Dr. W. E. Castle in animal genetics and Dr. E. M. East in plant genetics had joined this group and as an assistant to Wheeler had been added Mr. C. T. Brues, Instructor in Economic Entomology.

Following the establishment of the Bussey Faculty a number of other biologists joined its ranks and with its growth in advanced students the Bussey quickly became under Wheeler's leadership an institution for biological research, known the world over. As an administrative officer Wheeler was not always a complacent one for the university official to deal with. He was strenuously insistent that the institution of which he had charge should be properly manned and sufficiently supported and his insistence often brought him into conflict with those whose duty it was to provide the means to these ends. Never in any sense self-seeking, Wheeler nevertheless could on occasion assume a rigorously militant attitude when the general welfare of the Bussey was at stake and much of its remarkable growth at his hands depended upon the ability of its Dean to obtain resources from those who to him seemed to have but a niggardly conception of the functions of the Institution.

Wheeler's publications during this period numbered nearly three hundred. They were predominantly entomological and chiefly concerned with ants though they frequently dealt with these creatures in their most general phases. Many of his contributions had to do with the social life of ants and of other insects much of which was summarized, often with a delicately ironical turn, in his volumes "Social Life among the Insects" (1923), "Les Sociétés d'Insectes" (1926), "Foibles of Insects and Men" (1928), and "The Social Insects, their Origin and Evolution" (1928).

His interest in the philosophy of biology came to the surface in his vigorous espousal of Alexander's theory of emergent

evolution as shown in his article in Science "Emergent Evolution and the Social" (1926), and in his two booklets "Emergent Evolution and the Social" (1927) and "Emergent Evolution and the Development of Societies" (1928) in both of which he pointed out that any animal society was as much a soil for emergent growth as was the single creature. To him Hobbes' conception of society as an organism was a self-evident fact of nature. His historical feeling for his subject appeared in his discovery and translation of a lost manuscript by Réaumur, "The Natural History of Ants" (1926), and in the editing and publication with his colleague Dr. Thomas Barbour of "The Lamarck Manuscripts at Harvard" (1933). His essays of this period include such choice efforts as "The Termitodoxa, or Biology and Society" (1920), in which Wee-Wee, the Neotenic King of the 8,429th Dynasty of the Bellicose Termites discourses on the advantages of the white-ants' social life as compared with that of man, and "The Dry-Rot of Our Academic Biology" (1923) in which with cutting humor the "flubdub" of the academic biological world is laid bare. These are but a few of the choice fruits from the last of Wheeler's harvests.

When Wheeler in 1908 came to Harvard he took up residence in Jamaica Plain not far from the Bussey Building. As the Bussey was located in Forest Hills some eight miles from Cambridge his Harvard colleagues in natural history, mostly resident in Cambridge, saw relatively little of him. When the new Biological Laboratories were opened in Cambridge in September, 1931, in close proximity to the Museum of Comparative Zoology, it was decided to transfer the members of the Bussey Institution to this new location and provision was made for them in the new building. Wheeler with others came to the new situation and there began a life of much greater intimacy with the Cambridge biologists. Meanwhile in 1924 he had changed his residence from Jamaica Plain to Boston and thus came to live much nearer to the Cambridge centers. In his new Harvard surroundings he settled down with great complacency having two private laboratories, one in the Museum of Comparative Zoology among the insect collections and the other in the Biological Laboratories. That he spent more time in the latter than in the former resulted

from his habit of smoking while at work. Smoking because of fire risk was prohibited in the Museum, but was allowed in the Biological Laboratories.

Wheeler always arrived early in Cambridge for his day there, being usually driven in a car from Boston by his daughter. By nine o'clock he was to be found, as a rule, at his laboratory table in the biological building. Here he commonly worked till about noon, when he repaired to the Museum, where in the quarters of its Director, he took lunch. This mid-day rendezvous called by its frequenters "the eateria" was a center to which were invited many of the biological notables temporarily in Cambridge. It was therefore an interesting and stimulating gathering to which Wheeler added much and in which he took great delight. In the afternoon he usually worked either in his quarters in the Museum or in those in the Biological Laboratories. In the late afternoon he was driven back to his home where, if there were no social engagements, he was to be found in his study amidst books and manuscripts.

It was after a day much as that just described that he died suddenly of heart failure in Cambridge. He had dined at home and then for some unknown reason had been led to return to Cambridge, probably to make good some omission of the day. He could have stayed in Cambridge only a short time, for his death took place on the Boston-bound platform at the Harvard Subway Station early in the evening. This was on Patriots' Day, the nineteenth of April, 1937. He was survived by all his immediate family, his wife, Mrs. Dora Emerson Wheeler; his son, Dr. Ralph Emerson Wheeler; and his daughter, Miss Adeline Wheeler.

Wheeler was quietly fond of those he chose for his daily companions and he had in the best sense a warm heart for those nearest to him. Like his beloved ants, he was essentially social. In Boston he was often to be seen at the meetings of the Thursday Club and the dinners of the Academy Round Table and he was the center of a small group of older men who met informally at luncheon week by week in reminiscence of their European student days and early life. On all such occasions he was a

charming and delightful companion full of wit and rich in anecdote.

He was elected a member of the National Academy of Sciences in 1912 and attended its meetings with much regularity. He also held membership in many other scientific societies such as the American Philosophical Society, the American Academy of Arts and Sciences, the American Association for the Advancement of Science, the American Zoological Society of which he was a past president, the American Society of Naturalists, the American Ecological Society, of which he was at one time vice-president, the Philadelphia Academy of Natural Sciences, the Boston Society of Natural History, vice-president at the time of his death, the Washington Academy of Science, the New York Academy of Science, and, among foreign societies, the Zoological Societies of France and of Belgium, and the Entomological Societies of London, of France, and of Belgium. He was the recipient of the Elliot Medal from the National Academy of Sciences (1922) and of the Leidy Medal from the Philadelphia Academy of Natural Sciences (1931). In 1925 he served as Harvard Exchange Professor with France. He held honorary degrees from a number of universities: Doctor of Science from the University of Chicago (1916), from Harvard University (1930), and from Columbia University (1933) and doctor of Laws from the University of California (1933). In 1934 the French Republic made him an Officer in the Legion of Honor. Wheeler took a real pleasure in the distinctions bestowed upon him, but these honors never disturbed his unassuming demeanor and native modesty. The presentation of the Elliot Medal called from him an interesting account connected with his early friendship with Carl Akeley. It shows at once Wheeler's unbounded sense of humor even when the occasion was the reception of a very high honor, the Elliot Medal. It cannot be narrated better than in his own words:

"In 1894, soon after returning to the University of Chicago where I was then instructor in embryology with Professor Whitman, I learned that Akeley was at the Field Museum. I naturally looked forward to a renewal of our old intimacy but was informed that this was impossible. It seems that Professor Elliot, whom I had never met, disliked the zoological department

of the University, probably because of its strong morphological bias and the outspoken contempt of a few of its members for taxonomy, and I was naturally included as a *persona ingrata*. Moreover, he realized that he had captured a prize in Carl Akeley and was afraid that the secrets of his technique might leak out and be appropriated by some other museum. He therefore forbade any visits and kept Akeley closely confined, and as he worked every day and far into every night, I was able to see him only once or twice during all the years I was still to remain in Chicago. Professor Elliot's procedure was not devoid of humor, because I was, of course, perfectly familiar with Akeley's methods and could have made no use of them even had I wished to do so. Many years later fate brought an ironical atonement when the National Academy of Sciences conferred on me a medal which had been established by this same Professor Elliot!"

Wheeler was an omnivorous reader and he consumed volumes at a prodigious rate. His early and thorough training in languages received under the rigid discipline of his German schoolmasters in Milwaukee remained with him throughout his life. He had full command of Greek and of Latin so that he read the classics in these languages with ease. He would even pick up a modern Greek newspaper and work his way through a paragraph. The chief European tongues of today were at his command. In consequence he could read almost anything that seemed worth while. He was as familiar with Aristophanes as with Aristotle, and what was true of Greek was also true of Latin, French, German, and English. A passage from a modern Spanish novel was once read to him in English translation. He took it down at once to reread it in the original, for he was certain it would have a finer turn in the Spanish phrasing than in the English translation. His hours of reading were any spare time. When a close companion happened to be away with him at a scientific meeting or other such gathering and occupied the same room or an adjoining one, Wheeler would often wake at some such hour as six, call to hear if his companion too was awake, and if so, he would begin reading aloud at this early morning hour from some volume he had near at hand. Thus an unusual moment was made to serve his purpose. Notwithstanding his statements to the contrary, what he read he remembered, but he did not hesitate to reread books many times. It

has been well said of him that he was "possibly the most widely read member of his university," for his reading included belles-lettres as well as science, in short all literature.

As a result of his early, excellent training in languages and of his wide acquaintance with letters, his own style was unusual in clarity and literary flavor; to quote again from a recent appreciation of him, his writing had "a force and a polish, not to mention other qualities, that recall Voltaire. His printed contributions to his subject will perpetuate his scientific memory, and his less technical writings will be read with interest and amusement for a long time to come."

Wheeler's reading and reflection led him to approach special biological problems with a breadth of view not always shown by his colleagues. He was well versed in the history of his science and he was fully aware that that science and in fact science in general was no longer the handmaid of philosophy. Science in itself was to him a growing and gradually all-pervading system of philosophy. This view is now so generally accepted even by the modern philosopher himself that he has given up the invention of systems and shapes his conceptions on what science is gradually discovering. He no longer constructs frames into which science is supposed to fit. Wheeler was perfectly at home in this concept and did his share as a guide to philosophic thinking. He knew the systems of the past as did few others, even the professed philosopher, and yet he was not overawed by them, but chose to dissect them and adopt from them in an eclectic way what they seemed to contain for the present. His truly remarkable acquaintance with what had gone before as well as his unusual linguistic attainments made it possible for one of the wisest of our living thinkers, Professor Whitehead, to characterize him as the only man he had ever known who would have been both worthy and able to sustain a conversation with Aristotle. Yet, as has been pointed out, Wheeler was always soundly scientific in that he relied on the gathering of rigidly controlled observations and the consolidation of these into consistent general concepts as the basis for a universal understanding. Such general views as he held came naturally to him from biological fields and were the outcome of research in these realms. Well he knew the uncer-

tainties and hazards of this kind of occupation, but at no time did he even falter in his belief in ultimate conquest by the scientific method.

One general problem that keenly interested him and on which he repeatedly wrote was that of organic evolution. To him the history of organisms had as much significance for their understanding as their immediate activities had. In this he strongly opposed many in the modern school of general physiology and particularly his old associate Jacques Loeb. Intense and heated were their discussions on this topic. So far as organic evolution is concerned, Wheeler accepted without reserve the importance of Darwin's Natural Selection, but he was no Neo-Darwinist and he never ceased to maintain that the Lamarckian Principle had not been really disproved. It might still have much in it that was worthy of serious consideration. For evolutionary projects and speculation such as these, Loeb and his associates had little or no use and yet the trend of modern biology, much as it has been directed and shaped by these physiological workers, seems now to be turning toward Wheeler's position.

To those who knew Wheeler personally, he was a quiet, modest, unassuming man, the last in the world to reach for distinction and yet happy in its reception. Nevertheless he could be roused to passion, even to strong passion, particularly when the situation seemed to him to carry with it injustice, covered deceit, or insincerity. To none of these indirections would he yield a point and friend or foe must answer him in the open. Yet this passionate side of his nature was not shown to all. In his sketch of Carl Akeley, already quoted, he remarks, "I cannot recall that we were ever even on the verge of a quarrel," and there were many whose personal relations with him were never disturbed by so much as a ripple. Wheeler is too near the present generation to allow any one to form an estimate of his genius, for genius he had in the fullest sense. As a man of scientific letters he was supreme. He was possessed of extraordinary knowledge. He was worthy of all and more than all the distinctions that came to him. His sincerity was beyond reproach. To paraphrase from a recent tribute to him, he was a great experience in the lives of those who knew him and his departure leaves a void that nothing can fill.

BIBLIOGRAPHY OF WILLIAM MORTON WHEELER

1885-1937

For the preparation of the following list of publications by Professor Wheeler, the author of this Biographical Memoir is under obligation to Professor C. T. Brues and Professor F. M. Carpenter.

1885

Catalogue of Specimens of Mollusca and Brachiopoda for Sale at Ward's Natural Science Establishment. Rochester, New York, 167 pp.

A List of Trees found in the City of Milwaukee. Proc. Wisconsin Pharmaceut. Assoc., 1885, 24-25.

1887

Distribution of Coleoptera along the Lake Michigan Beach of Milwaukee County. Proc. Wisconsin Nat. Hist. Soc., 1887, 132-140.

1888

The Flora of Milwaukee Co., Wisconsin. Proc. Wisconsin Nat. Hist. Soc., 1888, 154-190.

The Spiders of the Sub-family Lyssomanae. (With G. W. and E. G. Peckham). Trans. Wisconsin Acad. Sci. Arts and Lett., **2**, 222-256.

1889

The Embryology of *Blatta germanica* and *Doryphora decemlineata*. Journ. Morph., **3**, 291-386.

Homologues in Embryo Hemiptera of the Appendages of the First Abdominal Segment of other Insect Embryos. American Naturalist, **23**, 644-645.

Ueber drüsenartige Gebilde im ersten Abdominalsegment der Hemipterenembryonen. Zool. Anzeig., **12**, 500-504.

On Two Species of Cecidomyid Flies Producing Galls on *Antennaria plantaginifolia*. Proc. Wisconsin Nat. Hist. Soc., 1889, 209-216.

Two Cases of Insect Mimicry. Proc. Wisconsin Nat. Hist. Soc., 1889, 217-221.

1890

Description of Some New North American Dolichopodidae. Psyche, **5**, 337-343, 355-362, 373-379.

The Supposed Bot-fly Parasite of the Box-turtle. Psyche, **5**, 403.

Review of Poulton's "Colors of Animals". Science, **16**, 286.

Hydrocyanic Acid Secreted by *Polydesmus virginicus* Drury. Psyche, **5**, 442.

Review of R. H. Lamborn's "Dragon-Flies versus Mosquitoes". Science, **16**, 284.

On the Appendages of the first Abdominal Segment of Embryo Insects. Trans. Wisconsin Acad. Sci. Arts and Lett., **4**, 87-140.

Note on the Oviposition and Embryonic Development of *Xiphidium ensiferum* Scud. Insect Life, 2, 222-225.

Ueber ein eigenthümliches Organ in Locustidenembryo. Zool. Anzeig., 13, 475-480.

1891

The Embryology of a Common Fly. Psyche, 6, 97-99.

The Germ-band of Insects. Psyche, 6, 112-115.

Neuroblasts in the Arthropod Embryo. Journ. Morph., 4, 337-343.

Hemidiptera haeckelii. Psyche, 6, 66-67.

1892

Concerning the "Blood-tissues" of the Insects. Psyche, 6, 216-220, 233-236, 253-258.

A Dipterous Parasite of the Toad. Psyche, 6, 249.

1893

A Contribution to Insect Embryology. Inaugural Dissertation. Journ. Morph., 8, 1-160.

The Primitive Number of Malpighian Vessels in Insects. Psyche, 6, 457-460, 485-486, 497-498, 509-510, 539-541, 545-547, 561-564.

1894

Syncœlidium pellucidum, a new Marine Triclad. Journ. Morph., 9, 167-194.

Planocera inquilina, a Polyclad inhabiting the Gill chamber of *Sycotypus canaliculatus.* Journ. Morph., 9, 195-201.

Protandric Hermaphroditism in Myzostoma. Zool. Anzieg., 6, 177-182.

1895

The Behavior of the Centrosome in the Fertilized Egg of *Myzostoma glabrum* Leuck. Journ. Morph., 10, 305-311.

Translation of Wilhelm Roux's "The Problems, Methods and Scope of Developmental Mechanics." Biol. Lectures Marine Biol. Lab. Woods Hole, 1894, 149-190.

1896

The Sexual Phases of Myzostoma. Mitth. Zool. Station Neapel, 12, 227-302.

The Genus Ochthera. Entom. News, 7, 121-123.

Two Dolichopodid Genera new to America. Entom. News, 7, 152-156.

A New Genus and Species of Dolichopodidae. Entom. News, 7, 185-189.

A New Empid with Remarkable Middle Tarsi. Entom. News, 7, 189-192.

An Antenniform Extra-appendage in *Dilophus tibialis* Loew. Arch. Entwickl.-Mech. Organism., 3, 261-268.

1897

A Genus of Maritime Dolichopodidae New to America. Proc. California Acad. Sci., 1, 145-152.

The Maturation, Fecundation and Early Cleavage of *Myzostoma glabrum* Leuckart. Arch. Biol., 15, 1-77.
Two Cases of Mimicry. Chicago Univ. Record, vol. 2, p. 1.
[Marine Fauna of San Diego Bay, California]. Science, 5, 775-776.

1898

A New Genus of Dolichopodidae from Florida. Zool. Bull., 1, 217-220.
Burger and Carrière on the Embryonic Development of the Wall-bee (Chalicodoma). American Naturalist, 32, 794-798.
Review of A. S. Packard's "Text Book of Entomology". Science, 7, 834-836.
A New Peripatus from Mexico. Journ. Morph., 15, 1-8.

1899

George Baur's Life and Writings. American Naturalist, 33, 15-30.
The Life History of Dicyema. Zool. Amzeig., 22, 169-176.
Anemotropism and Other Tropisms in Insects. Archiv. Entwickl.-Mech. Organism., 8, 373-381.
The Prospects of Zoölogical Study in Texas. Texas University Record, 1, 335-339.
New Species of Dolichopodidae from the United States. Proc. California Acad. Sci., Zoöl., 2, 1-84.
The Development of the Urinogenital Organs of the Lamprey. Zool. Jahrb. Abth. Morph., 13, 1-88.
J. Beard on the Sexual Phases of Myzostoma. Zool. Anzieg., 22, 281-288.
Kaspar Friedrich Wolff and the Theoria Generationis. Biol. Lectures Marine Biol. Lab., Woods Hole, 1899, 265-284.

1900

The Free-swimming Copepods of the Woods Hole Region. Bull. U. S. Fish Commission for 1899, 157-192.
On the Genus Hypocharassus Mik. Entom. News, 11, 423-424.
The Study of Zoölogy. Univ. of Texas Record, 2, 125-135.
Review of Korschelt and Heider's "Text-book of Embryology". Science, 11, 148-149.
The Female of *Eciton sumichrasti* Norton, with some notes on the habits of Texan Ecitons. American Naturalist, 34, 563-574.
The Habits of *Myrmecophila nebrascensis* Bruner. Psyche, 9, 111-115.
A Singular Arachnid (*Koenenia mirabilis* Grassi) Occurring in Texas American Naturalist, 34, 837-850.
A New Myrmecophile from the Mushroom Gardens of the Texan Leaf Cutting Ant. American Naturalist, 34, 851-862.
A Study of Some Texan Ponerinae. Biol. Bull., 2, 1-31.
The Habits of Ponera and Stigmatomma. Biol. Bull., 2, 43-69.

1901

The Males of Some Texan Ecitons. American Naturalist, **35**, 157-173. (With W. H. Long).

Impostors Among Animals. Century Magazine, **62**, 369-378.

The Compound and Mixed Nests of American Ants. American Naturalist, **35**, 431-448, 513-539, 701-724, 791-818.

Microdon Larvae in Pseudomyrma Nests. Psyche, **9**, 222-224.

The Parasitic Origin of Macroërgates among Ants. American Naturalist, **35**, 877-886.

An Extraordinary Ant-Guest. American Naturalist, **35**, 1007-1016.

Notices biologique sur les fourmis Mexicaines. Ann. Soc. Entom. Belgique, **45**, 199-205.

1902

A New Agricultural Ant from Texas, with Remarks on the North American Species. American Naturalist, **36**, 85-100.

Review of G. N. Calkins "Biology of the Protozoa". American Naturalist, **36**, 214-215.

A Consideration of S. B. Buckley's "North American Formicidae". Trans. Texas Acad. Sci., **4**, 17-31.

Empididae. Biol. Centrali-Americana. Diptera (Supplement) 366-376. (With A. L. Melander).

A Neglected Factor in Evolution. Science, **15**, 766-774.

Natural History, Oecology or Ethology? Science, **15**, 971-976.

Formica fusca Linn. subsp. *subpolita* Mayr. var. *perpilosa* n. var. Mem. y Rev. Soc. Cient. "Antonia Alzate", Mexico, **17**, 141-142.

New Agricultural Ants from Texas. Psyche, **9**, 387-393.

Translation of Carlo Emery's "An Analytical Key to the Genera of the Family Formicidae, for the Identification of the Workers". American Naturalist, **36**, 707-725.

Review of "Temperaturverhältnisse bei Insekten" by P. Bachmetjew. American Naturalist, **36**, 401-405.

Review of "The Elements of Insect Anatomy" by J. H. Comstock and V. L. Kellogg. Science, **16**, 351-352.

An American Cerapachys, with Remarks on the Affinities of the Cerapachyinae. Biol. Bull., **3**, 181-191.

The Occurrence of *Formica cinera* Mayr and *Formica rufibarbis* Fabricius in America. American Naturalist, **36**, 947-952.

1903

Review of James Mark Baldwin's "Development and Evolution". Psyche, **10**, 70-80.

Erebomyrma, A New Genus of Hypogaeic Ants from Texas. Biol. Bull., **4**, 137-148.

Dimorphic Queens in an American Ant (*Lasius latipes* Walsh). Biol. Bull., **4**, 149-163 (with J. F. McClendon).

Ethological Observations on an American Ant (*Leptothorax emersoni* Wheeler). Arch. Psychol. Neurol., 2, 1-31.

A Revision of the North American Ants of the Genus Leptothorax. Proc. Acad. Nat. Sci. Philadelphia, 1903, 215-260.

Review of T. W. Headley's "Problems of Evolution". Psychol. Rev., 10, 193-199.

A Decade of Texan Formicidae. Psyche, 10, 93-111.

The North American Ants of the Genus Stenamma (*sensu stricto*). Psyche, 10, 164-168.

How Can Endowments be Used Most Effectively for Scientific Research? Science, 17, 577-579.

The Origin of Female and Worker Ants from the Eggs of Parthenogenetic Workers. Science, 18, 830-833.

Review of "Report on the Collections of Natural History made in the Antarctic Regions during the Voyage of the "Southern Cross", London, 1902. Bull. American Geog. Soc., 35, 572-573.

Some Notes on the Habits of *Cerapachys augustæ*. Psyche, 10, 205-209.

Extraordinary Females in three Species of Formica, with Remarks on Mutation in the Formicidae. Bull. American Mus. Nat. Hist., 19, 639-651.

Some New Gynandromorphous Ants, with a Review of the Previously Recorded Cases. Bull. American Mus. Nat. Hist., 19, 653-683.

1904

Translation of August Forel's "Ants and Some Other Insects. An inquiry into the Psychic Powers of these Animals with an Appendix on the Peculiarities of their Olfactory Sense". The Monist, 14, 33-36. Reprinted as No. 56 of the Religion of Science Library, Chicago, 1904, 1-49.

Three New Genera of Inquiline Ants from Utah and Colorado. Bull. American Mus. Nat. Hist., 20, 1-17.

Review of C. W. Dodge's "General Zoology Practical, Systematic and Comparative". Science, 18, 824-825.

Review of E. E. Austen's "A Monograph of the Tsetse-flies (Genus Glossima, Westwood) based on the Collection in the British Museum". Bull. American Geog. Soc., 35, 573-575.

Woodcock Surgery. Science, 19, pp. 347-350.

The Obligations of the Student of Animal Behavior. The Auk, 21, 251-255.

A Crustacean-eating Ant (*Leptogenys* (*Lobopelta*) *elongata* Buckley). Biol. Bull., 6, 251-259.

The American Ants of the Subgenus Colobopsis. Bull. American Mus. Nat. Hist., 20, 139-158.

Dr. Castle and the Dzierzon Theory. Science, 19, 587-591.

The Ants of North Carolina. Bull. American Mus. Nat. Hist., 20, 299-306.

On the Pupation of Ants and the Feasibility of Establishing the Guatemalan Kelep, or Cotton-Weevil Ant in the United States. Science, **20**, 437-440.
Social Parasitism Among Ants. American Mus. Journ., **4**, 74-75.
A New Type of Social Parasitism Among Ants. Bull. American Mus. Nat. Hist., **20**, 347-375.
The Phylogeny of the Termites. Biol. Bull., **8**, 29-37.
Some Further Comments on the Guatemalan Boll Weevil Ant. Science, **20**, 766-768.

1905 and 1906

An Interpretation of the Slave-making Instincts in Ants. Bull. American Mus. Nat. Hist., **21**, 1-16.
Ethology and the Mutation Theory. Science, **21**, 535-540.
The Ants of the Bahamas, with a List of the Known West Indian Species. Bull. American Mus. Nat. Hist., **21**, 79-135.
Some Remarks on Temporary Social Parasitism and the Phylogeny of Slavery among Ants. Biol. Centralbl., **25**, 637-644.
New Species of Formica. Bull. American Mus. Nat. Hist., **21**, 267-274.
Ants from Catalina Island, California. Bull. American Mus. Nat. Hist., **20**, 269-271. Also in Bull. Southern California Acad. Sci., **4**, 60-63.
The Structure of Wings. Bird Lore, **7**, 257-262.
A New Myzostoma, Parasitic in a Starfish. Biol. Bull., **8**, 75-78.
How the Queens of the Parasitic and Slave-making Ants Establish their Colonies. American Mus. Journ., **5**, 144-148.
The North American Ants of the Genus Dolichoderus. Bull. American Mus. Nat. Hist., **21**, 305-319.
The North American Ants of the Genus Liometopum. Bull. American Mus. Nat. Hist., **21**, 321-333.
An Annotated List of the Ants of New Jersey. Bull. American Mus. Nat. Hist., **21**, 371-403.
Ants from the Summit of Mount Washington. Psyche, **12**, 111-114.
Worker Ants with Vestiges of Wings. Bull. American Mus. Nat. Hist., **21**, 405-408.
Dr. O. F. Cook's "Social Organization and Breeding Habits of the Cotton-Protecting Kelep of Guatemala". Science, **21**, 706-710.
The Habits of the Tent-building Ant (*Crematogaster lineolata* Say). Bull. American Mus. Nat. Hist., **22**, 1-18.
On the Founding of Colonies by Queen Ants, with Special Reference to the Parasitic and Slave-making Species. Bull. American Mus. Nat. Hist., **22**, 33-105.
On Certain Tropical Ants Introduced into the United States. Entom. News, **17**, 23-26.
The Ant Queen as a Psychological Study. Popular Science Monthly, **68**, 291-299.
The Kelep Excused. Science, **23**, 348-350.

Pelastoneurus nigrescens Wheeler, a synonym of *P. dissimilipes* Wheeler: a Correction. Entom. News, **17**, 69.

New Ants from New England. Psyche, **13**, 38-41.

Fauna of New England. List of the Formicidae. Occas. Papers, Boston Soc. Nat. Hist., **7**, 1-24.

A New Wingless Fly (*Puliciphora borinquenensis*) from Porto Rico. Bull. American Mus. Nat. Hist., **22**, 267-271.

The Ants of Japan. Bull. American Mus. Nat. Hist., **22**, 301-328.

The Ants of the Grand Canyon. Bull. American Mus. Nat. Hist., **22**, 329-345.

The Ants of the Bermudas. Bull. American Mus. Nat. Hist., **22**, 347-352.

Concerning *Monomorium destructor* Jerdon. Entom. News, **17**, 265.

An Ethological Study of Certain Maladjustments in the Relations of Ants to Plants. Bull. American Mus. Nat. Hist., **22**, 403-418.

The Expedition to Colorado for Fossil Insects. The American Mus. Journ., **6**, 199-203.

1907

A Collection of Ants from British Honduras. Bull. American Mus. Nat. Hist., **23**, 271-277.

The Polymorphism of Ants, with an Account of Some Singular Abnormalities due to Parasitism. Bull. American Mus. Nat. Hist., **23**, 1-93.

Notes on a New Guest Ant, *Leptothorax glacialis*, and the varieties of *Myrmica brevinodis* Emery. Bull. Wisconsin Nat. Hist. Soc., **5**, 70-83.

On Certain Modified Hairs Peculiar to the Ants of Arid Regions. Biol. Bull., **13**, 185-202.

The Fungus-growing Ants of North America. Bull. American Mus. Nat. Hist., **23**, 669-807.

The Origin of Slavery Among Ants. Popular Science Monthly, **71**, 550-559.

Pink Insect Mutants. American Naturalist, **41**, 773-780.

1908

The Ants of Porto Rico and the Virgin Islands. Bull. American Mus. Nat. Hist., **24**, 117-158.

Comparative ethology of the European and North American Ants. Journ. Psychol. Neurol., **13**, 404-435.

The Ants of Jamaica. Bull. American Mus. Nat. Hist., **24**, 159-163.

Ants from Moorea, Society Islands. Bull. American Mus. Nat. Hist., **24**, 165-167.

Ants from the Azores. Bull. American Mus. Nat. Hist., **24**, 169-170.

Vestigial Instincts in Insects and Other Animals. American Journ. Psychol., **19**, 1-13.

Studies on Myrmecophiles. II. Hetaerius. Journ. New York Entom. Soc., **16**, 135-143.

The Ants of Texas, New Mexico and Arizona. I. Bull. American Mus. Nat. Hist., 24, 399-485.
Honey Ants, with a Revision of the American Myrmecocysti. Bull. American Mus. Nat. Hist., 24, 345-397.
The Polymorphism of Ants. Ann. Ent. Soc. America, 1, 39-69.
Studies on Myrmecophiles. I. Cremastochilus. Journ. New York Entom. Soc., 16, 68-79.
The Ants of Casco Bay, Maine, with Observations on Two Races of *Formica sanguinea* Latreille. Bull. American Mus. Nat. Hist., 24, 619-645.
A European Ant (*Myrmica levinodis*) Introduced into Massachusetts. Journ. Econ. Entom, 1, 337-339.
Studies on Myrmecophiles. III. Microdon. Journ. New York Entom. Soc., 16, 202-213.

1909

A Small Collection of Ants from Victoria, Australia. Journ. New York Entom. Soc., 17, 25-29.
Ants collected by Professor Filippo Silvestri in Mexico. Boll. Lab. Zool. Gen. e. Agrar. R. Scuola Sup. Agric. Portici, 3, 228-238.
Review of P. Deegener's "Die Metamorphose der Insekten". Science, 29, 384-387.
Predarwinian and Postdarwinian Biology. Popular Science Monthly, 74, 381-385.
Ants Collected by Professor Filippo Silvestri in the Hawaiian Islands. Boll. Lab. Zool. Gen. e. Agrar. R. Scuola Sup. Agric. Portici, 3, 269-272.
Ants of Formosa and the Philippines. Bull. American Mus. Nat. Hist., 26, 333-345.
A Decade of North American Formicidae. Journ. New York Entom. Soc., 17, 77-90.
A New Honey Ant from California. Journ. New York Entom. Soc., 17, 98-99.
The Ants of Isle Royale, Michigan. Report Michigan Geol. Surv., 1908, 325-328.
Review of A. D. Hopkins "The Genus Dendroctonus". Journ. Econ. Entom., 2, 471-472.
Observations on Some European Ants. Journ. New York Entom. Soc., 17, 172-187.

1910

Ants: Their Structure, Development and Behavior. (Columbia University Biological Series vol. 9, xxv + 663.)
Two New Myrmecophilous Mites of the Genus Antennophorus. Psyche, 17, 1-6.

Review of W. Dwight Pierce's "A Monographic Revision of the Twisted Winged Insects Comprising the Order Strepsiptera Kirby". Journ. Econ. Entom., **3**, 252-253.

Small Artificial Ant-Nests of Novel Patterns. Psyche, **17**, 73-75.

Review of H. Friese's "Die Bienen Afrikas". Science, **31**, 580-582.

The Effects of Parasitic and Other Kinds of Castration in Insects. Journ. Exper. Zool., **8**, 377-438.

Colonies of Ants (*Lasius neoniger* Emery) Infested with *Laboulbenia formicarum* Thaxter. Psyche, **17**, 83-86.

An Aberrant Lasius from Japan. Biol. Bull., **19**, 130-137.

Three New Genera of Myrmicine Ants from Tropical America. Bull. American Mus. Nat. Hist., **28**, 259-265.

A New Species of Aphomomyrmex from Borneo. Psyche, **17**, 131-135.

A Gynandromorphous Mutillid. Psyche, **17**, 186-190.

The North American Forms of *Lasius umbratus* Nylander. Psyche, **17**, 235-243.

The North American Forms of *Camponotus fallax* Nylander. Journ. New York Entom. Soc., **18**, 216-232.

The North American Ants of the Genus Camponotus Mayr. Ann. New York Acad. Sci., **20**, 295-354.

A List of New Jersey Formicidae in J. B. Smith's Report of the Insects of New Jersey, 1910, 655-663.

1911

The Ant-Colony as an Organism. Journ. Morph., **22**, 307-325.

Additions to the Ant-fauna of Jamaica. Bull. American Mus. Nat. Hist., **30**, 21-29.

Review of K. Escherich's "Termitenleben auf Ceylon". Science, **33**, 530-534.

On *Melanetærius infernalis* Fall. Psyche, **18**, 112-114.

Two Fungus-Growing Ants from Arizona. Psyche, **18**, 93-101.

A New Camponotus from California. Journ. New York Entom. Soc., **19**, 96-98.

Three Formicid Names which have been Overlooked. Science, **33**, 858-860.

Ants Collected in Grenada, W. I., by Mr. C. T. Brues. Bull. Mus. Comp. Zool., **54**, 167-172.

Review of v. Kirchner's "Blumen und Insekten". Science, **34**, 57-58.

A List of the Type Species of the Genera and Subgenera of Formicidae. Ann. New York Acad. Sci., **21**, 157-175.

Literature for 1910 on the Behavior of Ants, their Guests and Parasites. Journ. Anim. Behavior, **1**, 413-429.

Notes on the Myrmecophilous Beetles of the Genus Xenodusa, with a description of the Larva of *X. cava* Leconte. Journ. New York Entom. Soc., **19**, 163-169.

Pseudoscorpions in Ant Nests. Psyche, **18**, 166-168.

Descriptions of Some New Fungus-growing Ants from Texas, with Mr. C. G. Hartman's Observations on their Habits. Journ. New York Entom. Soc., 19, 245-255.

An Ant-nest Coccinellid (*Brachyacantha 4-punctata* Mels.) Journ. New York Entom. Soc., 19, 169-174.

Miastor Larvae in Connecticut. Journ. New York Entom. Soc., 19, 201.

Lasius (*Acanthomyops*) *claviger* in Tahiti. Journ. New York Entom. Soc., 19, 262.

A Desert Cockroach. Journ. New York Entom. Soc., 19, 262-263.

Three New Ants from Mexico and Central America. Psyche, 18, 203-208.

Insect Parasitism and its Peculiarities. Popular Science Monthly, 79, 431-449.

1912

The Ants of Guam. Journ. New York Entom. Soc., 20, 44-48.

New Names for Some North American Ants of the Genus Formica. Psyche, 19, 90.

Notes on a Mistletoe Ant. Journ. New York Entom. Soc., 20, 130-133.

Notes About Ants and Their Resemblance to Man. Nat. Geogr. Mag., 23, 731-766.

Additions to our Knowledge of the Ants of the Genus Myrmecocystus Wesmael. Psyche, 19, 172-181.

The Male of *Eciton vagans* Olivier. Psyche, 19, 206-207.

Review of J. H. Comstock's "Spider Book". Science, 36, 745-746.

1913

Notes on the Habits of Some Central American Stingless Bees. Psyche, 20, 1-9.

A Giant Coccid from Guatemala. Psyche, 20, 31-33.

Review of Sladen's "The Humble Bee, its Life History and How to Domesticate it". Science, 37, 180-182.

A. Revision of the Ants of the Genus Formica (L) Mayr. Bull. Mus. Comp. Zool., 53, 379-565.

Observations on the Central American Acacia Ants. Trans. 2nd Internat. Entom. Congress, Oxford, 1912, 2, 109-139.

Hymenoptera II; Ants (Formicidae). Rec. Indian Mus., 8, 233-237.

Corrections and Additions to the "List of the Type Species of Genera and Subgenera of Formicidae". Ann. New York Acad. Sci., 23, 77-83.

Ants Collected in Georgia by Mr. J. C. Bradley and Mr. W. T. Davis. Psyche, 20, 112-117.

The Ants of Cuba. Bull. Mus. Comp. Zool., 54, 477-505.

Ants Collected in the West Indies. Bull. American Mus. Nat. Hist., 32, 239-244.

A Solitary Wasp (*Aphilanthops frigidus* F. Smith) that Provisions its Nest with Queen Ants. Journ. Anim. Behavior, 3, 374-387.

1914

The Ants of the Baltic Amber. Schrift. Physik-ökonom. Gesellsch. Königsberg, **55**, 1-142.

The Ants of Haiti. Bull. American Mus. Nat. Hist., **33**, 1-61. (With W. M. Mann).

Gynandromorphous Ants Described During the Decade 1903-1913. American Naturalist, **48**, 49-56.

Ants Collected by Mr. W. M. Mann in the State of Hidalgo, Mexico. Journ. New York Entom. Soc., **22**, 37-61.

Review of O. M. Reuter's "Lebensgewohnheiten und Instinkte der Insekten bis zum Erwachem der sozialen Instinkte". Science, **39**, 69-71.

Formica exsecta in Japan. Psyche, **21**, 26-27.

Notes on the Habits of Liomyrmex. Psyche, **21**, 76-77.

Ants and Bees as Carriers of Pathogenic Microörganisms. American Journ. Trop. Diseases and Prevent. Med., **2**, 160-168.

The American Species of Myrmica Allied to *M. rubida* Latreille. Psyche, **21**, 118-122.

New and Little Known Harvesting Ants of the Genus Pogonomyrmex. Psyche, **21**, 149-157.

1915

The Luminous Organ of the New Zealand Glow-worm. Psyche, **22**, 36-43. (With F. X. Williams).

A New Linguatulid from Ecuador. Rept. First Harvard Exped. to South America (1913), appendix, 207-208.

Neomyrma *versus* Oreomyrma, a Correction. Psyche, **22**, 50.

Some Additions to the North American Ant-fauna. Bull. American Mus. Nat. Hist., **34**, 389-421.

The Australian Honey-Ants of the Genus Leptomyrmex Mayr. Proc. American Acad. Arts and Sci., **51**, 255-286.

Paranomopone, a New Genus of Ponerine Ants from Queensland. Psyche, **22**, 117-120.

Hymenoptera. In "Scientific Notes on an Expedition into the Northwestern Regions of South Australia". Trans. Roy. Soc. South Australia, **39**, 805-823.

A New Bog-inhabiting Variety of *Formica fusca* L. Psyche, **22**, 203-206.

Two New Genera of Myrmicine Ants from Brazil. Bull. Mus. Comp. Zool., **59**, 45-54.

On the Presence and Absence of Cocoons among Ants, the Nest-spinning habits of the Larvae and the Significance of the Black Cocoons Among Certain Australian Species. Ann. Entom. Soc. America, **8**, 323-342.

1916

The Marriage-flight of a Bull-dog Ant (*Myrmecia sanguinea* F. Smith). Journ. Anim. Behavior, **6**, 70-73.

Formicoidea. In "The Hymenoptera of Connecticut". Connecticut State Geol. & Nat. Hist. Surv., Bull. 22, 577-601.
Prodiscothyrea, a New Genus of Ponerine Ants from Queensland. Trans. Roy. Soc. South Australia, **40**, 33-37.
The Australian Ants of the Genus Onychomyrmex Emery. Bull. Mus. Comp. Zool., **60**, 45-54.
Ants Collected in British Guiana by the Expedition of the American Museum of Natural History during 1911. Bull. American Mus. Nat. Hist., **35**, 1-14.
The Ants of the Phillips Expedition to Palestine during 1914. Bull. Mus. Comp. Zool., **60**, 167-174. (With W. M. Mann.)
Ants Collected in Trinidad by Professor Roland Thaxter, Mr. F. W. Urich and Others. Bull. Mus. Comp. Zool., **60**, 323-330.
Jean-Henri Fabre. Journ. Anim. Behavior, **6**, 74-80.
Four New and Interesting Ants from the Mountains of Borneo and Luzon. Proc. New England Zool. Club, **6**, 9-18.
Review of H. St. J. K. Donisthorpe's "British Ants, Their Life-History and Classification". Science, **43**, 316-318.
Some New Formicid Names. Psyche, **23**, 40.
Notes on Some Slave Raids of the Western Amazon Ant (*Polyergus breviceps Emery*). Journ. New York Entom. Soc., **24**, 107-118.
The Australian Ants of the Genus Aphaenogaster Mayr. Trans. Roy. Soc. South Australia, **40**, 213-223.
The Mountain Ants of Western North America. Proc. American Acad. Arts Sci., **52**, 457-569.
Note on the Brazilian Fire Ant, *Solenopsis sævissima* F. Smith. Psyche, **23**, 142-143.
An Anomalous Blind Worker Ant. Psyche, **23**, 143-145.
Questions of Nomenclature Connected with the Ant Genus Lasius and its Subgenera. Psyche, **23**, 168-173.
Two New Ants from Texas and Arizona. Proc. New England Zool. Club, **6**, 29-35.
A Phosphorescent Ant. Psyche, **23**, 173-174.
An Indian Ant Introduced into the United States. Journ. Econ. Entom., **9**, 566-569.
The Australian Ant-Genus Myrmecorhynchus Ern. André and its Position in the Subfamily Camponotinae. Trans. Roy. Soc. South Australia, **41**, 14-19.
Ants Carried in a Floating Log from the Brazilian Mainland to San Sebastian Island. Psyche, **23**, 180-183.

1917

A New Malayan Ant of the Genus Prodiscothyrea. Psyche, **24**, 29-30.
A List of Indiana Ants. Proc. Indiana Acad. Sci., 1917, 460-466.
The North American Ants Described by Asa Fitch. Psyche, **24**, 26-29.
The Ants of Alaska. Bull. Mus. Comp. Zool., **61**, 15-22.

The Phylogenetic Development of Apterous and Subapterous Castes in the Formicidae. Proc. Nat. Acad. Sci., 3, 109-117.

The Synchronic Behavior of Phalangidae. Science, 45, 189-190.

Jamaican Ants Collected by Prof. C. T. Brues. Bull. Mus. Comp. Zool., 61, 457-471.

The Temporary Social Parasitism of *Lasius subumbratus* Viereck. Psyche, 24, 167-176.

Notes on the Marriage Flights of Some Sonoran Ants. Psyche, 24, 177-180.

The Pleometrosis of Myrmecocystus. Psyche, 24, 180-182.

1918

The Ants of the Genus Opisthopsis Emery. Bull. Mus. Comp. Zool., 62, 343-362.

The Australian Ants of the Ponerine Tribe Cerapachyini. Proc. American Acad. Arts Sci., 53, 215-265.

Ants Collected in British Guiana by Mr. C. William Beebe. Journ. New York Entom. Soc., 26, 23-28.

A Great Opportunity for Applied Science. Harvard Alumni Bulletin, 20, 264-266.

A Study of Some Ant Larvae, with a Consideration of the Origin and Meaning of the Social Habit among Insects. Proc. American Philos. Soc., 57, 293-343.

Vermileo comstocki sp. nov., an Interesting Leptid fly from California. Proc. New England Zool. Club, 6, 83-84.

Quick Key to a Knowledge of Common Insects: Review of F. E. Lutz's "Field Book of Insects." American Mus. Journ., 18, 381-382.

Introduction to Phil and Nellie Rau's "Wasp Studies Afield." Princeton Univ. Press, 1918, 1-8.

1919

Two Gynandromorphous Ants. Psyche, 26, 1-8.

The Parasitic Aculeata, A Study in Evolution. Proc. American Philosoph. Soc., 58, 1-40.

The Ants of Borneo. Bull. Mus. Comp. Zool., 63, 43-157.

A New Subspecies of *Aphænogaster treatæ* Forel. Psyche, 26, 50.

The Ant Genus Lordomyrma Emery. Psyche, 26, 97-106.

A New Paper-making Crematogaster from the Southeastern United States. Psyche, 26, 107-112.

The Ants of Tobago Island. Psyche, 26, 113.

The Ant Genus Metapone Forel. Ann. Entom. Soc. America, 12, 173-191.

The Ants of the Galapagos Islands. Proc. California Acad. Sci., 2, 259-297.

The Ants of Cocos Island. Proc. California Acad. Sci., 2, 299-308.

A Singular Neotropical Ant (*Pseudomyrma filiformis* Fabricius). Psyche, 26, 124-131.

The Phoresy of Antherophagus. Psyche, 26, 145-152.

1920

The Termitodoxa, or Biology and Society. Scientific Monthly, **10**, 113-124.

The Subfamilies of Formicidae, and Other Taxonomic Notes. Psyche, **27**, 46-55.

Euponera gilva Roger, a Rare North American Ant. Psyche, **27**, 69-72. (With F. M. Gaige).

Charles Gordon Hewitt. Journ. Econ. Entom., **13**, 262-263.

The Feeding Habits of Pseudomyrmine and Other Ants. Trans. American Philos. Soc., **22**, 235-279. (With I. W. Bailey).

Review of Bouvier "La Vie Psychique des Insectes." Science, **52**, 443-446.

1921

A New Case of Parabiosis and the Ant Gardens of British Guiana. Ecology, **2**, 89-103.

The Organization of Research. Science, **53**, 53-67.

Chinese Ants. Bull. Mus. Comp. Zool., **64**, 529-547.

Observations on Army Ants in British Guiana. Proc. American Acad. Arts Sci., **56**, 291-328.

Professor Emery's Subgenera of the Genus Camponotus Mayr. Psyche, **28**, 16-19.

A Study of Some Social Beetles in British Guiana and of Their Relations to the Ant-plant, Tachigalia. Zoologica, New York, **3**, 35-126.

The Tachigalia Ants. Zoologica, New York, **3**, 137-168.

Notes on the Habits of European and North American Cucujidae. Zoologica, New York, **3**, 173-183.

On Instincts. Journ. Abnorm. Psyche, **15**, 295-318.

Chinese Ants Collected by Prof. C. W. Howard. Psyche, **28**, 110-115.

Vespa arctica Rohwer, a Parasite of *Vespa diabolica* De Saussure. Psyche, **28**, 135-144. (With L. H. Taylor).

1922

Ants of the Genus Formica in the Tropics. Psyche, **19**, 174-177.

The Ants of Trinidad. American Mus. Novitates, No. 45, 1-16.

A New Genus and Subgenus of Myrmicinae from Tropical America. American Mus. Novitates, No. 46, 1-6.

Report on the Ants of the Belgian Congo. Bull. American Mus. Nat. Hist., **45**, 1-1139. (With the collaboration of J. Bequaert, I. W. Bailey, F. Santschi, and W. M. Mann). I. On the Distribution of the Ants of the Ethiopian and Malagasy Regions, 13-37. II. The Ants Collected by the American Museum Congo Expedition, 39-270. VII. Keys to the Genera and Subgenera of Ants, 631-710. VIII. A Synonymic List of the Ants of the Ethiopian Region, 711-1004. IX. A Synonymic List of the Ants of the Malagasy Region, 1005-1055.

Observations on *Gigantiops destructor* Fabricius, and Other Leaping Ants. Biol. Bull., **42**, 185-201.

Neotropical Ants of the Genera Carebara, Tranopelta and Tranopeltoides, New Genus. American Mus. Novitates, No. 48, 1-14.

The Mating of Diacamma. Psyche, **29**, 203-211. (With J. W. Chapman).

1923

The Dry-Rot of Our Academic Biology. Science, **57**, 61-71.

A Singular Habit of Sawfly Larvae. Psyche, **30**, 9-13. (With W. M. Mann).

Formicidae from Easter Island and Juan Fernandez. In "The Natural History of Juan Fernandez and Easter Island." Ed. by Dr. Carl Skottsberg, **3**, 317-319.

Report on the ants Collected by the Barbados-Antigua Expedition from the University of Iowa in 1918. Univ. of Iowa Studies Nat. Hist., **10**, 3-9.

Social Life Among the Insects. Scientific Monthly, **14**, 497-525; **15**, 67-88; 119-131; 235-256; 320-337; 385-404; 527-541; **16**, 5-33; 159-176; 312-329.

Chinese Ants Collected by Professor S. F. Light and Professor A. P. Jacot. American Mus. Novitates, No. 69, 1-6.

Formicidae. Wissenschaftliche Ergebnisse der Schwedischen entomologischen Reise des Herrn Dr. A. Roman in Amazonas 1914-1915. Arkiv. Zool., **15**, 1-6.

Social Life Among the Insects. New York, 3+375.

Ants of the Genera Myopias and Acanthoponera. Psyche, **30**, 175-192.

The Occurrence of Winged Females in the Ant Genus Leptogenys Roger, with Descriptions of New Species. American Mus. Novitates, No. 90, 16 pp.

1924

Two Extraordinary Larval Myrmecophiles from Panama. Proc. Nat. Acad. Sci., **10**, 237-244.

A Gynandromorph of *Tetramorium guineënse* Fabr. Psyche, **31**, 136-137.

Hymenoptera of the Siju Cave, Garo Hills, Assam. Records of the Indian Museum, **26**, 123-125.

On the Ant-genus Chrysapace Crawley. Psyche, **31**, 224-225.

The Formicidae of the Harrison Williams Expedition to the Galapagos Islands. Zoologica, New York, **5**, 101-122.

Ants of Krakatau and Other Islands in the Sunda Strait. Treubia, **5**, 1-20.

1925

Courtship of the Calobates; The Kelep Ant and the Courtship of its Mimic *Cardiacephala myrmex*. Journ. Heredity, **15**, 485-495.

A New Guest-Ant and other new Formicidae from Barro Colorado Island, Panama. Biol. Bull., **49**, 150-181.

The Ants of the Philippine Islands. Part I. Dorylinae and Ponerinae. Philippine Journ. Sci., **28**, 47-73. (With J. W. Chapman.)
Neotropical Ants in the Collections of the Royal Museum of Stockholm. Part I. Ark. Zool., **17A**, 1-55.
Zoological Results of the Swedish Expedition to Central Africa 1921. Insecta 10, Formicidae. Ark. Zool., **17A**, 1-3.
The Finding of the Queen of the Army ant *Eciton hamatum* Fabricius. Biol. Bull., **49**, 139-149.
L'Evolution des Insectes Sociaux. Rev. Scient., **63**, 548-557.
Carlo Emery. Entom. News, **36**, 318-320.

1926

Les Sociétés d'Insectes: leur origine, leur évolution. Paris, 468 pp.
Translation of an unpublished manuscript of Réaumur, "The Natural History of Ants." New York, 280 pp.
Social Habits of Some Canary Island Spiders. Psyche, **33**, 29-31.
A New Word for an Old Thing. (Review of Watson's "Behaviorism.") Quarterly Rev. Biol., **1**, 439-443.
Emergent Evolution and the Social. Science, **44**, 433-440.
Ants of the Balearic Islands. Folia Myrmecologica et Termitologica, **1**, 1-6.

1927

The Occurrence of *Formica fusca* Linné in Sumatra. Psyche, **34**, 40-41.
Burmese Ants Collected by Professor G. E. Gates. Psyche, **34**, 42-46.
Chinese Ants Collected by Professor S. F. Light and Professor N. Gist Gee. American Mus. Novitates, No. 255, 1-12.
The Physiognomy of Insects. Quarterly Rev. Biol., **2**, 1-36.
Ants Collected by Professor F. Silvestri in Indochina. Boll. Lab. Zool. Gen. Agrar., Portici, **20**, 83-106.
Ants of the Genus Amblyopone Erichson. Proc. American Acad. Arts Sci., **62**, 1-29.
A Few Ants from China and Formosa. American Mus. Novitates, No. 259, 1-4.
The Ants of the Canary Islands. Proc. American Acad. Arts Sci., **62**, 93-120.
The Ants of Lord Howe and Norfolk Island. Proc. American Acad. Arts Sci., **62**, 121-153.
Carl Akeley's Early Work and Environment. Natural History, **27**, 133-141.
The Occurrence of the Pavement Ant (*Tetramorium cæspitum*) in Boston. Psyche, **34**, 164-165.
Conserving the Family, a Review of three books on Human Reproduction and the Family. Journ. Hered., **18**, 119-120.
Emergent Evolution and the Social. Psyche Miniatures, Gen. Ser. No. 11, London.

1928

Foibles of Insects and Men. New York, XXVI + 217 + XI pp.
The Social Insects, their Origin and Evolution. London, 378 pp.
Ants Collected by Prof. F. Silvestri in China. Boll. Lab. Zool. Gen. Agrar., Portici, **22**, 3-38.
The Evolution of Ants. In F. Mason "Creation by Evolution," 210-224.
A New Species of Probolomyrmex from Java. Psyche, **35**, 7-9.
Ants of Nantucket Island, Mass. Psyche, **35**, 10-11.
Mermis Parasitism and Intercastes among Ants. Journ. Exper. Zool., **50**, 165-237.
Ants Collected by Prof. F. Silvestri in Japan and Korea. Boll. Lab. Zool. Gen. Agrar., Portici, **21**, 96-125.
Emergent Evolution and the Development of Societies. New York, 80 pp.
Zatapinoma, a new Genus of Ants from India. Proc. New England Zool. Club, **10**, 19-23.
Societal Evolution in E. V. Coundry's "Human Biology and Racial Welfare." New York, pp. 135-155.

1929

Amazonian Myrmecophytes and their Ants. Zool. Anz. (Wasmann-Festband), **82**, 10-39. (With J. C. Bequaert.)
Two Interesting Neotropical Myrmecophytes (*Cordia nodosa* and *C. alliodora*). IV. Int. Congress of Entom., Ithaca, **2**, 342-353.
Present Tendencies in Biological Theory. Scientific Monthly, **28**: 97-109.
The Identity of the Ant-genera Gesomyrmex Mayr and Dimorphomyrmex Ernest André. Psyche, **36**, 1-12.
Three New Genera of Ants from the Dutch East Indies. American Mus. Novitates, No. 349, 1-8.
Ants Collected by Professor F. Silvestri in Formosa, The Malay Peninsula and the Philippines. Boll. Lab. Zool. Gen. Agrar., Portici, **24**, 27-64.
Two Neotropical Ants Established in the United States. Psyche, **36**, 89-90.
Note on Gesomyrmex. Psyche, **36**, 91-92.
The Ant-Genus Rhopalomastix. Psyche, **36**, 95-101.
A Camponotus Mermithergate from Argentina. Psyche, **36**, 102-106.
Some Ants from China and Manchuria. American Mus. Novitates, No. 361, 1-11.
Review of H. Friedmann's "The Cowbirds, A Study in the Biology of Social Parasitism." Science, **70**, 70-73.
The Entomological Discoveries of John Hunter. In "Exercises in Celebration of the Bicentenary of the Birth of John Hunter." New England Journ. Medicine, 1929, 810-823.
Is *Necrophylus arenarius* Roux the larva of *Pterocroce storeyi* Withycombe? Psyche, **36**, 313-320.

1930

History of the Bussey Institution. In S. E. Morison's "Development of Harvard University since the Inauguration of Pres. Elliot 1869-1929," 508-517.

The Ant *Prenolepis imparis* Say. Ann. Entom. Soc. America, **23**, 1-24.

A Second Note on Gesomyrmex. Psyche, **37**, 35-40.

Two New Genera of Ants from Australia and the Philippines. Psyche, **37**, 41-47.

Two Mermithergates of Ectatomma. Psyche, **37**, 48-54.

Formosan Ants Collected by Dr. R. Takahashi. Proc. New England Zool. Club, **11**, 93-106.

A New Emeryella from Panama. Proc. New England Zool. Club, **12**, 9-13.

A New Parasitic Crematogaster from Indiana. Psyche, **37**, 55-60.

Review of Auguste Forel's "Social World of the Ants." Journ. Soc. Psychol., **1**, 170-177.

Philippine Ants of the Genus Aenictus with Descriptions of the Females of Two Species. Journ. New York Entom. Soc., **38**, 193-212.

Ant-tree Notes from Rio Frio, Colombia. Psyche, **37**, 107-117. (With P. J. Darlington, Jr.)

Demons of the Dust, A Study in Insect Behavior. New York, XVIII + 378 pp.

1931

New and Little-known Species of Macromischa, Croesomyrmex and Antillaemyrmex. Bull. Mus. Comp. Zool., **72**, 3-34.

A List of the Known Chinese Ants. Peking Nat. Hist. Bull., **5**, 53-81.

What is Natural History? Bull. Boston Soc. Nat. Hist., No. 59, 3-12.

Concerning Some Ant Gynandromorphs. Psyche, **38**, 80-85.

Neotropical Ants of the Genus Xenomyrmex Forel. Rev. Entom., **1**, 129-139.

Hopes in the Biological Sciences. Proc. American Philos. Soc., **70**, 231-239.

The Ant *Camponotus* (*Myrmepomis*) *sericeiventris* Guérin and its Mimic. Psyche, **38**, 86-98.

1932

Ænictoteras chapmani gen. et sp. nov., an Extraordinary Ant-Guest from the Philippines. Liv. du Centenaire Soc. Entom. France, 1932, 301-310.

Ants of the Marquesas Islands. Bull. 98, Bernice P. Bishop Mus., Honolulu, 155-163.

Ants from the Society Islands. Pacific Ent. Survey Publ. 6, article 3, pp. 13-19.

A Cuban Vermileo. Psyche, **38**, 166-169.

A List of the Ants of Florida. Journ. New York Entom. Soc., **40**, 1-17.

How the Primitive Ants of Australia Start their Colonies. Science, **76**, 532-533.

Some Attractions of the Field Study of Ants. Scientific Monthly, **34**, 397-402.

An Australian Leptanilla. Psyche, **39**, 53-58.

1933

Colony-founding among Ants, with an Account of Some Primitive Australian species. Cambridge, 179 pp.

The Lamarck Manuscripts at Harvard. Cambridge, 202 pp. (With T. Barbour.)

Mermis Parasitism in Some Australian and Mexican Ants. Psyche, **40**, 20-31.

Unusual Prey of Bembix. Psyche, **40**, 57-59. (With R. Dow.)

Formicidae of the Templeton Crocker Expedition in 1933. Proc. California Acad. Sci., **21**, 57-64.

New Ants from China and Japan. Psyche, **40**, 65-67.

A Second Parasitic Crematogaster. Psyche, **40**, 83-86.

Translation of Maurice Bedel's "My Uncles, Louis Bedel and Henri d'Orbigny." Rev. Biol., **8**, pp. 325-330.

A New Species of Ponera and Other Records of Ants from the Marquesas Islands. Bernice P. Bishop Mus., Honolulu, Bull. 114, 141-144.

An Ant New to the Fauna of the Hawaiian Islands. Proc. Hawaiian Entom. Soc., **8**, 275-278.

A New Myrmoteras from Java. Proc. New England Zool. Club, **13**, 72-75.

Three Obscure Genera of Ponerine Ants. American Mus. Novitates, No. 672, 1-23.

1934

Some Aberrant Species of Camponotus (Colobopsis) from the Fiji Islands. Ann. Entom. Soc. America, **27**, 415-424.

Ants from the Islands off the West Coast of Lower California and Mexico. Pan Pacific Entom., **10**, 132-144.

A Second Revision of the Ants of the Genus Leptomyrmex Mayr. Bull. Mus. Comp. Zool., **77**, 67-118.

A Revised List of the Ants of the Hawaiian Islands. Occasional Papers, Bernice P. Bishop Mus., Honolulu, **10**, 1-21.

A Study of the Ant Genera Novomessor and Veromessor. Proc. American Acad. Arts Sci., **69**, 341-387. (With W. S. Creighton.)

Animal Societies. Scientific Monthly, **39**, 289-301.

Formicidae of the Templeton Crocker Expedition 1932. Proc. California Acad. Sci., **21**, 173-181.

Contributions to the Fauna of Rottnest Island, West Australia. Journ. Roy. Soc. Western Australia, **20**, 137-163.

An Australian Ant of the Genus Leptothorax Mayr. Psyche, **41**, 60-62.

A Specimen of the Jamaican Vermileo. Psyche, **41**, 236-237.

Introduction to O. E. Plath's "Bumblebees, their Life History, Habits and Economic Importance", pp. vii-x.

Neotropical Ants Collected by Dr. Elisabeth Skwarra and Others. Bull. Mus. Comp. Zool., 77, 157-240.
Some Ants from the Bahama Islands. Psyche, 41, 230-232.

1935

Two New Genera of Myrmicine Ants from Papua and the Philippines. Proc. New England Zool. Club, 15, 1-9.
Observations on the Behavior of Animals during the Total Solar Eclipse of August 31st, 1932 (Insects by Wheeler). Proc. American Acad. Arts Sci., 70, 36-45.
The Ants of the Genera Belonopelta Mayr and Simopelta Mann. Rev. de Entomologia, 5, 8-19.
The Australian Ant-genus Mayriella Forel. Psyche, 42, 151-160.
A Checklist of the Ants of Oceania. Occasional Papers, Bernice P. Bishop Mus., Honolulu, 11, 1-56.
New Ants from the Philippines. Psyche, 42, 38-52.
Myrmecological Notes. Psyche, 42, 68-72.
Ants of the Genus Acropyga Roger with Description of a New Species. Journ. New York Entom. Soc., 43, 321-329.

1936

Binary Anterior Ocelli in Ants. Biol. Bull., 70, 185-192.
Entomology at Harvard University. From "Notes Concerning the History and Contents of the Museum of Comparative Zoology". Cambridge, pp. 22-32.
Ants from Hispaniola and Mona Island. Bull. Mus. Comp. Zool., 80, 196-211.
Notes on Some Aberrant Indonesian Ants of the Subfamily Formicinae. Tijdschr. Entom., 79, 217-221.
Review of Thomas Elliott Snyder's "Our Enemy the Termite". Psyche, 43, 27-29.
The Australian Ant-genus Froggattella Forel. American Mus. Novitates, No. 842, 1-12.
A Singular Crematogaster from Guatemala. Psyche, 43, 40-48.
Ecological Relations of Ponerine and Other Ants to Termites. Proc. American Acad. Arts Sci., 71, 159-243.
A Notable Contribution to Entomology. (Review of Tarlton Rayment's "A Cluster of Bees.") Quarterly Rev. Biol., 11, 337-341.
Ants from the Society, Austral, Tuamotu and Mangareva Islands. Occasional Papers, Bernice P. Bishop Mus., Honolulu, 12, 1-17.

1937

Additions to the Ant-fauna of Krakatau Island and Verlaten Island. Treubia, 16, 21-24.
Ants mostly from the Mountains of Cuba. Bull. Mus. Comp. Zool., 81, 439-465.
Mosaics and Other Anomalies Among Ants. Cambridge, 95 pp.

Marshall Avery Howe

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OF

MARSHALL AVERY HOWE

1867–1936

BY

WILLIAM ALBERT SETCHELL
With bibliography by
JOHN HENDLEY BARNHART

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1938

MARSHALL AVERY HOWE

1867–1936

BY WILLIAM ALBERT SETCHELL

Marshall Avery Howe was born at Newfane, Vermont, on June 6, 1867, and departed this life at his home in Pleasantville, Westchester County, New York, on December 24, 1936, in his seventieth year. At the time of his passing he occupied the position of Director of the New York Botanical Garden.

Marshall Avery Howe was the eldest of five children of Marshall Otis and Gertrude Isabelle Dexter Howe, both parents belonging to old Vermont families of English origin, remarkable for their longevity, their intellectual interests, and, particularly in the case of both his father and mother, for their scholarly inclinations and accomplishments. Both father and mother seem to have been interested in botany, among other nature subjects. Both parents seem to have been of that student and reading class, many of whom existed in rural New England even beyond the middle decades of the Nineteenth Century and whose influence for healthful living and logical thinking had its lasting effect upon their progeny and communicated itself to the community. Marshall Avery Howe was named after his father, Marshall Otis Howe (1832-1919) and his maternal grandfather, Avery Joseph Dexter (1818-1893) and was ever particularly insistent on the use of his full name, which is thoroughly distinctive.

With such parentage and ancestry, it is little wonder that Marshall Avery Howe not only showed forth early his propensities for study, but we can well believe that he received both sympathy and practical encouragement from his parents as well as the esteem and admiration of his fellow townsmen. Since the details of parentage, early education and influences are of such importance in the rounding out and shaping of a career, it seems best to quote several paragraphs of a letter from his brother, Professor Clifton Durant Howe, Dean of the Faculty of Forestry of the University of Toronto, who has kindly supplied them for the information of the writer of this memoir.

"First, in regard to our background, I know hardly anything about my father's ancestors except from general knowledge. I think he was a mutant. His father was a farmer for most of his life; in the earlier part of his life he was a fuller. From the few things I remember my father saying, it is probable that his mother had greater mentality than his father. My father had two sisters and one brother who lived to be in the late twenties and thirties, but who were not outstanding in any way, in fact they all three died of what was then called 'quick consumption.' My father also contracted the disease and was given only a few years to live by his doctors. He had prepared himself for the law and was nearly ready to be admitted to the bar when he began to have hemorrhages. The doctor told him the only chance he had of living, and that for only a few years, was to farm. He married a strong healthy woman and had five boys, all robust and healthy and Marshall's death was the first among them.

"My father lived on a farm all his life but I can hardly say that he got his living by farming. He wasn't strong and robust enough to eke a living out of one of those stony New England farms. The Yankee trading instinct was fairly well developed in him. He made more money buying and selling live stock than he made from agricultural crop production. At one time he even bought raw furs from the trappers in the county. For thirty years or so he was agricultural editor of the local rural paper, furnishing a column every week, and I think got originally two dollars and a half for it and in the end he may have got up as high as five dollars. He wrote particularly upon the trend of agriculture in Vermont, a downward trend which began just after the Civil War and has continued ever since. These articles attracted a good deal of attention outside the state and he was asked to contribute, I remember, to the New England Homestead and to some of the New England magazines. He always took a great interest in education and was superintendent of the schools of the township for twenty-five or thirty years. He was the old-fashioned type of naturalist, interested in all forms of life. He collected plants, specialized particularly upon the grasses and sedges. I can remember that he sent some speci-

mens to old Sereno Watson at Harvard who did not even place his plant in the right genus. My father kept at him until he acknowledged his mistake. He knew all the minerals and collected them. We still have several barrels of his minerals in the barn at the old farm, but the labels have been lost and they are not good for much now. He organized an agricultural library in Newfane village which later grew into a very fine town library. Although he never made any money farming, himself, he knew how it should be done and was the first man in his community to spray his potato vines. He introduced a leguminous crop in the rotation. He also introduced the Jersey cow into the community. He practised forestry in his woodlot except that he did not know it by that name. As boys we were not allowed to cut any straight growing young trees, we were not even allowed to put a straight pole on the old-fashioned pole fences. His care of the hundred acre woodlot served a good purpose, for the revenue from the sale of it, when he became too old to work, supported him for quite a number of years. When I was talking about my father's health as a young man I intended to add that he died in his eighty-seventh year.

"I think, of course, that my mother was an exceptional woman. She taught a country school before she was sixteen years of age. When she was very young, about twenty years old, she made a herbarium of local plants. I still have it and it is in fairly good condition. At intervals during her youth and early married life she contributed short poems to the local papers, all rather philosophical. She organized a circulating magazine club and a discussion club among her neighbors. I can remember one winter when the women met at our house to study some of Shakespeare's plays and at another time Browning's poems. My mother was in her eighty-sixth year when she died.

"Marshall was the first born and was always precocious in his school work. He completed his matriculation Latin and his mathematics by the time he was fourteen years old and this was done mostly in the public school. In those days many of the public school teachers were part way or all the way through college. I can distinctly remember Marshall trudging off to the village on a winter's night, after the farm chores were done, to

recite Latin lessons to the district school teacher. I can also remember my mother drilling him in conjugations and declensions although she was mostly self taught in Latin. He taught his first school before entering high school. I think it was the winter before he was sixteen. He never really went to high school, as we understand the term now, but to one of those good old New England academies or seminaries at the present time nearly extinct. I do not think he spent more than two years actual time in one of those. He taught the winter term in the country schools to earn money for his board and tuition. The principal of the Glenwood Classical Institute of West Brattleboro, from which Marshall graduated was a very scholarly man and he took Marshall far beyond his matriculation requirements in nearly all his subjects. He thought so much of Marshall's attainments that he persuaded him to go back to him to teach Latin for a term during his sophomore year at the University of Vermont. I think Marshall was then in his twentieth year. Although the principal of the school was very fond of Marshall and tried to keep him, his influence must have been towards the study of the classics rather than botany.

"I really think the greatest influence was due to his lifelong friend, fellow-townsman, and fellow-classmate at the University of Vermont, Dr. Abel J. Grout. I think that Abel got interested in mosses before Marshall had thought of specializing in anything. When he did get down to this, he took up the Hepaticae so that he and Abel could work as closely together as possible. The Hepaticae were Marshall's predominant interest when he went to California and, as you know, his first considerable publication was concerned with them. I think his interest turned to marine algae while he was in California. Anyway, I can remember that he began collecting at that time.

"Naturally I feel that Marshall got his real start from the chromosomes that he inherited from his parents and to their continuous encouragement and example in guiding him in the paths of natural history.

"In reading over this letter after it was typed I perceive that I have ignored some of your suggestions. First, in regard to Marshall's early interest in botany, I can hardly remember when

he was not 'puttering' with plants. It certainly began before he left the public school. I can remember his using the oven in the summer kitchen stove in which to dry his 'blotters' and that he changed them very frequently to prevent the discoloration of the plants. Even as a boy he made complete and neat mounts."

Marshall Avery Howe was graduated from the University of Vermont in 1890 with the degree of Ph.B. He, like Sabbatini's hero, Bellarion, had no Greek, so he was constrained to follow the "Latin Scientific" course. He took the Freshman Latin Prize, was awarded distinction in Latin, French, chemistry, physics, mathematics, and zoology. He was elected "Class Leader" by his fellow students. Dr. Abel J. Grout, his roommate and chum, has spoken feelingly of these years in his sketch in "The Bryologist" (40:33-38, 1937, with portrait).

From both Dr. Grout and Marshall's brother, Clifton, it is evident that George H. Perkins, Professor of Natural History in the University of Vermont, must have had a most favorable influence on shaping the trend of the biological activity of both Marshall and his friend Grout. Professor L. R. Jones did not arrive at the University until Marshall's senior year.

On leaving college, Marshall Avery Howe taught almost a year in the Brattleboro High School, but was called, in the late summer of 1891, to the University of California at Berkeley, as Instructor in Cryptogamic Botany. The selection of young Howe was due to Edward Lee Greene, the Professor of Botany and "Head" of the Department. The steps leading to this selection must be interesting, for Greene was not in botanical sympathy at that time with most of his university colleagues of the country, but, at present, those steps are not clear. Young Howe apparently was not particularly happy during the earlier of the five years he spent in Berkeley, but was becoming reconciled to it about the time (1895) that Greene decided to leave the University of California for the Catholic University at Washington. The successor to Greene at the University of California (the writer) was a cryptogamic botanist, thus making two in the same general line at the University of California, and, as it did seem necessary to represent other divisions of botany, Howe resigned

at the end of the 1895-1896 college year to accept a fellowship in Columbia University of New York City.

The period of sojourn in California induced a series of lines of specialization on even such a conservative and deliberate New Englander (and a "Vermonter") as young Howe. His ancestry, working under such an environment as surrounded the brilliant, although opinionated and erratic Edward Lee Greene, put into expression his first dozen botanical articles of one type or another. Howe, even when younger, was slow and deliberate, although articulate and clear. Greene believed in publication, as well as preparation for, and planning for, publication. For *Pittonia* and for *Erythea,* journals conducted by, or founded by, Greene, Howe began his articles, notes, and reviews, having to do largely with Hepaticology (or Bryology) and the suggestions, or at least the influence, of Greene may be seen in the three "Chapters in early history of Hepaticology" (Erythea, 1894-1895). When Howe left California he took with him a very considerable collection of Californian Bryophytes for his future work. He had also made a beginning in Phycology, the other and perhaps preponderant specialty of his professional life. His paper entitled "A month on the shores of Monterey Bay" (Erythea, 1893) contained a report on, as well as a list of, the marine algae he collected, named after consultation with W. G. Farlow of Harvard and the Californian phycologist, Dr. C. L. Anderson of Santa Cruz, California. This "month," as well as other experience of marine algae, was prophetic, but Howe left California to continue his studies in Hepaticology with L. M. Underwood at Columbia University, and continued with certain of the groups of Hepaticae until the end of his life, but his phycological interests recrudesced after his connection with the New York Botanical Garden (1901) and his most distinctive botanical trend was with the marine algae.

Marshall Avery Howe received the degree of Ph.D. from Columbia University in 1898, and from 1898 to 1901 he was a Curator of the University Herbarium, at a time when the efforts of Nathaniel Lord Britton (Professor of Botany at Columbia) for creating the New York Botanical Garden in Bronx Park were materializing. In 1900, the main building of the Garden

was available for use and the herbarium of Columbia University was deposited in it. In 1901, Howe became a member of the Garden scientific staff and in 1906 was advanced to a full curatorship. From 1901 until his death in 1936, Howe was definitely associated with the New York Botanical Garden, being appointed Assistant Director in 1923, and finally, October 1, 1935, he was made Director, after the resignation of Elmer Drew Merrill. It now remains to outline as much as possible of his very varied and effective activities during his 35 years of official connection with the New York Botanical Garden, as collector, arranger of numerous exhibits, morphologist, taxonomist, and distributor of algae and hepaticae; likewise as editor, administrator, and expert and cultivator of dahlias and other ornamentals as educational exhibits. Much may be said, and with profit, about his activities along each and every one of these lines.

The New York Botanical Garden was organized to assemble as much as was possible and profitable of plants, both living and preserved either in proper liquids or dried. Much collecting must necessarily be done and the plants properly prepared for greenhouse, garden, museum, or herbarium, not neglecting material for exchange with other botanical institutions. Members of the staff, specialists, proceeded to various portions of the Atlantic seaboard and the West Indies (Britton's particular interest) for exploration of their floral content and for the critical study of, and report upon, these. The scheme proved effective and, from comparatively small collections, the institution has increased to one whose resources along plant lines are commensurate with the largest and best of its kind.

Beginning with his official connection with the New York Botanical Garden in 1901, Howe entered upon a full life, more intensive in field activities, in the preparation of museum and herbarium material, but continued to issue reports on the material assembled, at first chiefly general, later more and more special, as the algae of the explorations were worked over, the specimens distributed into the herbarium and museum, and the duplicate numbers sent out in profitable exchange.

It is not necessary to follow Howe in all his expeditions to

procure algae for the New York Botanical Garden and for distribution to other similar institutions, but some of the principal ones may be mentioned with profit. In 1900, he visited Bermuda; in 1901 he explored certain coasts of Nova Scotia and Newfoundland; in 1903, the Florida coasts were his objective and were touched again incidentally in 1904, 1909, and in 1914; Porto Rico in 1903 and again in 1915; the Bahama Islands in 1904 and 1908; Jamaica in 1907 and 1909; Panama and Colon in 1910; and Cuba in 1915. From all these and other places, Howe brought back a wealth of algae and other plants for both the material and scientific uses of his institution. Through his recommendation and through the private generosity of Director Britton, various algal herbaria were obtained in their entirety, such as that of Nicolas Pike, containing many specimens early collected from both coasts of North America and from the Island of Mauritius; that of the pioneer phycologist, Dr. C. L. Anderson of Santa Cruz, California, containing much of the California algal flora; and that of Frank S. Collins of Malden, Mass., fairly complete as to New England algae, North American Pacific Coast algae, and a wealth of exotic algae from all coasts of the world obtained by Collins in his exchanges with prominent collectors and phycological authorities of most of the civilized countries. In all, the collections of Algae at the Garden were augmented to 78,229 specimens and those of Hepaticae to 59,240 specimens during Howe's curatorship. The herbarium specimens are accompanied by thousands of microscope slides, prepared in connection with his critical studies, and the exhibit of Algae in the museum is not only extensive but most representative. Many thousands of specimens, most of them with printed labels, were sent out to the leading herbaria of the world and are of the utmost value in following out, critically, his numerous publications.

Marshall Avery Howe did not confine himself solely to the particular groups of plants assigned to his curatorship, but extended his interests and his usefulness to other lines of activity of the New York Botanical Garden. His home interest in ornamentals extended to the Garden. His major project at the Garden concerned the dahlias. Through his energy, care, and

careful planning, there was, during the last years of his life, a splendid collection of these ornamentals grown for display and horticultural study. The stands were excellent. Many horticultural varieties were represented, carefully named, with sources indicated, and they were effectively grouped. The autumnal display of dahlias was one of the popular and professional features of the Garden. Along with this went continuous publication of various papers, to extend the knowledge of varieties and methods of culture and care of dahlias.

Another series of "duties" which came with the curatorship was taking over the matter of editing and providing copy for the bulletins and reports of the Garden itself, or concerning some one or other of its features, for outside information. It seems that Howe was admirably adapted for this type of work, and from 1924 to his death he was editor of the *"Journal of the New York Botanical Garden."* His services were also called upon by the Torrey Botanical Club, and he was editor of its journal, *"Torreya"* and of its *"Bulletin of the Torrey Botanical Club"* for some time. He wrote many reviews of current literature in connection with these duties. His editorial and publicity work came in particularly in connection with the increasing executive work for the Garden, until he was finally definitely appointed Assistant Director (1923) and ultimately Director (1935).

All through his scientific and administrative career Marshall Avery Howe continued his research work, which falls principally under three heads: Hepaticology; Phycology, including the work of the calcareous Algae; and finally, ornamental plants, most largely dahlias. At first Howe was more generally Cryptogamic, and, although one finds nothing regarding Fungi, even in his earliest papers, Ferns, Mosses, Liverworts, and Algae were all passed under review. At the time of his leaving California there was strong impression that the Liverworts were to be his specialty and that seemingly led him to Columbia University and to Lucien Marcus Underwood. He retained his interest in this group, more particularly in the Ricciaceae and the Anthocerotaceae, until the last, but his main effort was more largely devoted, soon after he had finished up his monograph of

the California Liverworts (his doctor's thesis) to the marine Algae. In the latter years of his life, the dahlias came in and he was most active in their connection. By this time also, increasing administrative and editorial work must have cut seriously into his time and energy.

Hepaticology, as has been noted above, was Howe's earliest specialty, although his very first paper (1892) dealt with two Pacific North American Algae (*Fucus evanescens* Ag. and *Gigartina radula* Ag., together with notes on an abnormal form of a grass from Vermont). His most ambitious work on Hepatics was his "The Hepaticae and Anthocerotes of California" (1899), a work based on his five years of collecting in California and attendant and subsequent study. In this work are to be recognized the Marshall Avery Howe characteristics of careful and complete studies of morphology, taxonomic identity, as well as independence, and free discussion of relationships. The descriptions are drawn up by Howe in the full and extended fashion always employed by him and partly due to his own thoroughgoing fashion, possibly, in part, a reflection of the phytographic ideas of E. L. Greene, but more probably representing the meticulous ideas of the author himself. Howe believed in detailed descriptions, which became long, but never involved, and he continued this practice throughout his career.

After the publication on California Hepatics and the beginning of the papers on Algae (1901), the latter activity usurped the field and Howe retained chiefly the Ricciaceae, Sphaerocarpaceae, Riellaceae, and Anthocerotaceae, some of which he continued in cultivation, finally presenting some of these families (partly in collaboration with Caroline Coventry Haynes) in monographic form to Britton and Brown's "North American Flora" (1923). He still continued to be the leading authority in these families and contributed sporadically to the furthering of our knowledge concerning them. He also described (1922, in connection with Arthur Hollick) a presumably fossil Hepatic, under the name of *Jungermanniopsis Cockerellii,* from a Miocene shale in Colorado.

Marshall Avery Howe will, however, chiefly be remembered and estimated as a phycologist. Passing over the two earlier

papers dealing with certain of the marine Algae of California, the beginning of the new outlook came in 1901, when fresh from meeting the representatives of the marine flora of West Indian affinities at Bermuda (1900), he began with a paper dealing with certain of the calcareous green Algae (*"Acicularia"* and *"Acetabulum"*) of that flora. After exploring farther into the Florida and West Indian waters, he published more papers on the calcareous green Algae as well as some on non-calcareous Algae of this and other groups. Finally there came the papers (in connection with M. Foslie) on the "Nullipores" proper, or crustaceous calcareous red Algae, together with insight into their function in reef building, contributions towards our knowledge of marine sediments, etc. The ultimate result of this experience was the identification of certain of them as components of tertiary rocks in the Canal Zone (1918), on certain of the West Indian Islands (1922), from California (1934), and even from the Jurassic rocks of Montana (1925).

Marshall Avery Howe's studies on the marine Algae of the West Indian Islands, although not representing all that he published on marine Algae, stand with those of other writers as preeminent. He added much to our knowledge of the morphology, development, and taxonomy of all the groups of marine Algae and much elimination of confusion was accomplished by his critical examination of algal specimens during a trip to the older herbaria of Europe (1904) for the purpose of studying the type specimens of American marine Algae therein preserved. From the extensive notes of his studies and about 300 photographs to show habit, Howe was in a far better position to correlate his own studies on the shores, with what had been written or postulated by earlier and contemporary writers than were any of his predecessors. He certainly made full use of these unusual facilities and was a prominent factor in bringing order out of chaos throughout the extensive and most important West Indian marine flora.

In the West Indian marine flora, Marshall Avery Howe found the principal motive of his research work. The Caribbean Sea is a closed area of warm tropical and subtropical waters, characterized by its abundance of Corals and calcareous Algae. It

is a relatively shallow basin, largely segregated from the Atlantic by an island chain (the Greater and Lesser Antilles); from the Mediterranean, with which it has affinities, by the breadth of the Atlantic Ocean; and from the East Indian seas, with which it also has affinities, by the central American land mass and the Isthmus of Panama, as well as by the northern breadth of the Pacific Ocean. In many ways, it recalls, as do also the Mediterranean and East Indian seas, the conditions of the ancient Tethys. Howe realized more and more the especial problems of this remarkable body of water and, as his experience and knowledge of its calcareous marine Algae developed, he began to see more and more the relations between them and world problems. To many of us, the contributions towards solving the problems of the calcareous Algae were the most important of Howe's scientific life. A brief résumé of these may therefore be attempted, to elucidate his attitude toward them.

Among the calcareous Algae, so abundant on the coasts of the Caribbean Islands, Marshall Avery Howe first attacked those belonging to the Chlorophyceae (or green Algae). He most thoroughly investigated the West Indian species of *Acicularia, Acetabulum* (*Acetabularia*), the variable and troublesome species of *Halimeda,* and of *Neomeris.* Almost of necessity he made studies of the other complex *Siphonales,* which are little or not at all calcified. The contributions made to our knowledge of their vegetative structure and reproduction shed much light on their taxonomic relations, both within the genera, within the families, and within the order.

The second great group of calcareous Algae, occurring in profusion on the reefs of the Bahama Islands in particular, is that of the Crustaceous Corallines, a group of the red Algae, or Rhodophyceae. In the beginning he enlisted the collaboration of M. Foslie of Trondhjem, Norway, the great authority on these plants, but while Foslie may have been largely responsible for the final determinations, it was certainly Howe who not only made the collections and selected the specimens for study, but also prepared the sections which were used as the basis for making clear their structure and relationships. Foslie and Howe

published two papers (1906) on species from Florida, Bahama Islands, and Porto Rico. These publications, besides the excellent descriptions and discussions, were provided with a most excellent series of illustrations, both of general habit and of what is almost unique in the exposition of these plants, extraordinarily effective reproductions of photomicrographs of sections. Through these illustrations of microscopic structure a new era was instituted in the more exact study of the crustaceous corallines and the more massive of the Caribbean species were the first made available for effective comparison with other tropical species.

Through these studies and others not so definitely published, Howe became interested in two phases of the relation of the crustaceous corallines to world problems; viz., the relation of the crustaceous corallines to the building up of the huge structures known as "coral reefs," and the relation between the recent living crustaceous corallines and those, now extinct, of previous geologic ages.

Concerning the first, in 1912, he published a much needed discussion of the subject in *"Science,"* on "The Building of 'Coral' Reefs," in which, reviewing the general subject, he concludes that "the importance of the corals in reef-building has been much overestimated and that the final honors in this connection may yet go to the more humble lime-secreting plants."

On the fossil crustaceous corallines, he published several papers (1918, 1919, 1922, 1925, and 1934), in which his extensive knowledge of the living forms enabled him to interpret accurately their fossil representatives. From the marine crustaceous coralline and its relation to rock building came easily an interest in fresh water forms associated with the formation of travertines. He made some studies and many examinations of both recent and fossil material. Two publications (1931, 1932) resulted and more might have been expected. An appreciative note on his assistance in solving geological problems has been published since his death by T. Wayland Vaughan (Marshall Avery Howe, Jour. Paleont., 11, no. 4: 368-370, June, 1937) with pertinent bibliography (by Rosalie Weickert).

Of the calcareous reds other than the crustaceous corallines and as occurring in the Caribbean Sea, Marshall Avery Howe made many studies, the taxonomic being recorded in his various floras, but of the species of two genera he worked out and reported some fundamental facts leading to profound changes in our attitude towards their life histories and relationships. In 1917 and 1918 he brought forward facts and experience to indicate a structural, sexual dimorphism among species of *Galaxaura,* the adult alternative generations differing sufficiently to have been classified under different subgenera. In 1920, he published a detailed paper on the "monosporangial discs" of various species of *Liagora,* a new type of structure which had barely been mentioned previously, but which Howe suggests may be integral parts of the life history of the plants on which they occur rather than independent or obligate epi-endophytes.

Much more might be said of the strictly scientific work of Marshall Avery Howe, but suffice it to say that it was done meticulously, with insight, and thoroughness. One may turn to his application to his other duties, both as an official of the New York Botanical Garden and as a citizen. As administrator, his success was sufficient to cause him finally to be appointed to the directorship. On the horticultural side, he not only cultivated ornamentals in his own garden but instituted a display of dahlias at the New York Botanical Garden which was internationally famous. A glance through the appended bibliography will indicate the more than "amateurish" interest he took in this activity. He was a charter member of the Vermont Botanical Club (1895). At Pleasantville, N. Y., where he made his home for 22 years, he performed his duties to his fellow citizens as an active member and sometime president of its "Garden Club"; and served as secretary and later as president of the Board of Trustees of the Pleasantville Free Library. He was awarded a gold medal by the American Dahlia Society, was a Vice-president of the Associated Garden Clubs of New York, and was a member of the Board of Directors of the Horticultural Society of New York.

In recognition of his scientific work, he was awarded the

honorary degree of Sc.D. by his *alma mater,* the University of Vermont, in 1919, and he was elected a member of the National Academy of Sciences in 1923. He was a Fellow of the New York Academy of Sciences, which he served as President in 1934 and 1935. He was Vice-president of the Botanical Society of America in 1913 and was elected President for the year 1937, too late to be able to serve. He was also President of the Torrey Botanical Club for the year 1936.

His home life was quiet and dignified. At home in Newfane he was very busy with chores about the farm, his earlier intervals of evening teaching for board and tuition, and his botanizing and preparation of herbarium specimens. On June 8, 1909, he married, at Stratford, Conn., Edith Morton Packard, who passed away October 18, 1928, after some years of lingering illness. Two children, Gertrude Dexter Howe and Prentiss Mellen Howe, survive their father.

Marshall Avery Howe was of the older as well as one of the present generation. He began his vocational work in early childhood. He was a real "naturalist." Yet, as he later developed, he fell into the swing of modern ideas, still attending to many subjects but doing each well. His love for Hepaticae, his devotion to the Algae, and his successful work with his dahlias, all redound to his credit and indicate his thoroughness, his precision. His calm yet full-hearted enthusiasm, coupled with persistence and skill in communicating his results to others, were his especial and most admirable characteristics.

In preparing this memoir, use has been made of the following:

Marshall Avery Howe (Jour. N. Y. Bot. Garden, 38, no. 446: 25-31, Feb. 1937) by A. B. Stout.

Marshall Avery Howe (Jour. Paleont., 11, no. 4: 368-370, June 1937) by Thomas Wayland Vaughan (with bibliography on Calcareous Algae by Rosalie Weickert).

Marshall Avery Howe, 1867-1936 (Bryologist, 40, no. 2: 33-36, Mar.-Apr. 1937, with portrait) by A. J. Grout.

Much information was gratefully received from Professor Clifton Durant Howe of the Faculty of Forestry of the Uni-

versity of Toronto, one of the four surviving brothers of Marshall Avery Howe, and from Dr. Abel J. Grout of Newfane, Vt., and Manatee, Fla., Howe's close associate and roommate in college.

For the appended bibliography, all credit is due to Howe's associate for many years at the New York Botanical Garden, Dr. John Hendley Barnhart.

BIBLIOGRAPHY *

Miscellaneous notes. Pittonia **2**: 291. September 20, 1892.

Teratological notes. Erythea **1**: 18, 19. January 2, 1893.

[Review of] Peirce's The California vine disease. Erythea **1**: 24, 25. January 2, 1893.

A month on the shores of Monterey Bay. Erythea **1**: 63-68. March 1, 1893.

Two Californian Cryptogams. Erythea **1**: 112, 113, *pl. 1.* May 1, 1893.

A fern new to California. Erythea **2**: 51, 52. March 1, 1894.

Notes on Californian Bryophytes.—I. Erythea **2**: 97-101, *pl. 1, 2.* June 1, 1894.

Chapters in the early history of hepaticology.—I. Erythea **2**: 130-135. August 1, 1894;—II. Erythea **2**: 143-147. September 1, 1894;—III. Erythea **3**: 1-6. January 2, 1895;—IV. Erythea **3**: 25-30. February 1, 1895.

Evolution of the *Hepaticae.* Erythea **2**: 172. October 1, 1894. [Review.]

[Review of] Warming's A handbook of systematic botany [English translation by Potter]. Erythea **3**: 82-84. May 1, 1895.

Notes on Californian Bryophytes.—II. Erythea **4**: 48-54. March 5, 1896.

Spermatozoids in phanerogams. Bull. Torrey Club **24**: 96, 97. February 28, 1897. [Review.]

Gyrothyra, a new genus of *Hepaticae.* Bull. Torrey Club **24**: 201-205, *pl. 302, 303.* April 24, 1897.

Notes on Californian Bryophytes.—III. Erythea **5**: 87-94, *pl. 3.* August 31, 1897.

The North American species of *Porella.* Bull. Torrey Club **24**: 512-528. November 30, 1897.

The *Anthocerotaceae* of North America. Bull. Torrey Club **25**: 1-24, *pl. 321-326.* January 25, 1898.

Porella once more. Bull. Torrey Club **25**: 96-103. February 12, 1898.

New American *Hepaticae.* Bull. Torrey Club **25**: 183-192, *pl. 336, 337.* April 12, 1898.

The *Porella* question. Rev. Bryol. **25**: 75-78. October, 1898.

The *Hepaticae* and *Anthocerotes* of California. Mem. Torrey Club **7**: 1-208, *pl. 88-122.* August 5, 1899.

The microscopical exhibit. Jour. N. Y. Bot. Gard. **1**: 168-170. November, 1900.

[Review of] Brainerd, Jones, & Eggleston's Flora of Vermont. Torreya **1**: 10-12. January 29, 1901.

Riccia Beyrichiana and *Riccia dictyospora.* Bull. Torrey Club **28**: 161-165. March 27, 1901.

The Allen collection of *Characeae.* Jour. N. Y. Bot. Gard. **2**: 52-54. April, 1901.

* By John Hendley Barnhart.

Remarks on the use of *Funaria hygrometrica* in botanical teaching. Torreya 1: 39-41. April 19, 1901.

Contributions to the botany of the Yukon territory.—1. An enumeration of the *Hepaticae* collected by R. S. Williams 1898-1899. Bull. N. Y. Bot. Gard. 2: 101-105, *pl. 14.* May 27, 1901.

[Review of] Jepson's Flora of Western Middle California. Torreya 1: 69, 70. June 20, 1901.

Observations on the algal genera *Acicularia* and *Acetabulum.* Bull. Torrey Club 28: 321-334, *pl. 24, 25.* June 19, 1901.

Botanizing in Bermuda. Plant World 4: 101-104, *pl. 4, 5.* June, 1901.

Report of Dr. M. A. Howe, assistant curator, on a trip to Nova Scotia and Newfoundland. Jour. N. Y. Bot. Gard. 2: 177-180. December, 1901.

Notes on American *Hepaticae.* Bull. Torrey Club 29: 281-289. May 26, 1902.

An attempt to introduce a seaweed into the local flora. Jour. N. Y. Bot. Gard. 3: 116-118. June, 1902.

A note on the vitality of the spores of *Marsilia.* Torreya 2: 120-122. August 2, 1902.

The microscopical exhibit. Jour. N. Y. Bot. Gard. 3: 161-168, *f. 24.* September, 1902.

Caloglossa Leprieurii in mountain streams. Torreya 2: 149-152. September 30, 1902.

The microscopical exhibit at The New York Botanical Garden. Jour. Appl. Micros. and Lab. Meth. 5: 1990-1992, *f. 1, 2.* October, 1902.

Note on the "Report of the Brown-Harvard Expedition to Nachvak, Labrador." Torreya 2: 175. November 25, 1902.

Report of Dr. M. A. Howe, assistant curator, on a trip to Florida. Jour. N. Y. Bot. Gard. 4: 44-49, *f. 2-5.* March, 1903.

The genus *Riella,* with descriptions of new species from North America and the Canary Islands. [With L. M. Underwood.] Bull. Torrey Club 30: 214-224, *pl. 11, 12.* April 24, 1903.

[Review of] Grout's Mosses with hand-lens and microscope. Torreya 3: 106, 107. July 25, 1903.

A note on the "flowering" of the lakes in the Adirondacks. Torreya 3: 150-154. October 30, 1903.

Report on a trip to Porto Rico by Dr. M. A. Howe, assistant curator. Jour. N. Y. Bot. Gard. 4: 171-176, *f. 18-21.* October, 1903.

[Review of] Lett's Hepatics of the British Islands. Bryologist 7: 13, 14. January 12, 1904.

Notes on Bahaman algae. Bull. Torrey Club 31: 93-100, *pl. 6.* February 11, 1904.

The Museum exhibit of seaweeds. Jour. N. Y. Bot. Gard. 5: 56-63, *pl. 22* + *f. 9-12.* March, 1904.

The Pike collection of algae. Jour. N. Y. Bot. Gard. **5**: 86, 87. April, 1904.

Collections of marine algae from Florida and the Bahamas. Jour. N. Y. Bot. Gard. **5**: 164-166. August, 1904.

[Review of] Lloyd and Bigelow's The teaching of biology in the secondary school. Torreya **4**: 156-158. October 29, 1904.

Exogenous origin of antheridia in *Anthoceros*. Torreya **4**: 175-176. November 21, 1904.

Report on a trip to Europe. Jour. N. Y. Bot. Gard. **5**: 217-222, *f. 40, 41*. December, 1904.

Some of the coralline seaweeds in the Museum. Jour. N. Y. Bot. Gard. **6**: 59-64, *pl. 24, 25*. April, 1905.

Phycological studies.—I. New *Chlorophyceae* from Florida and the Bahamas. Bull. Torrey Club **32**: 241-252, *pl. 11-15*. May 27, 1905.

[Review of] Farlow's Bibliographical index of North American fungi. Torreya **5**: 200-202. November 25, 1905.

Phycological studies.—II. New *Chlorophyceae*, new *Rhodophyceae*, and miscellaneous notes. Bull. Torrey Club **32**: 563-586, *pl. 23-29*. December 6, 1905.

New American coralline algae. [With M. Foslie.] Bull. N. Y. Bot. Gard. **4**: 128-136, *pl. 80-93*. March 17, 1906.

Some photographs of the silk-cotton tree (*Ceiba pentandra*), with remarks on the early records of its occurrence in America. Torreya **6**: 217-231, *f. 1-6*. November 26, 1906. [Reprinted in] Bull. Dept. Agr. Jamaica **5**: 63-74, *f. 1-6*. 1907.

[Review of] Postelsia, the yearbook of the Minnesota Seaside Station. Torreya **6**: 250-253. December 15, 1906.

Two new coralline algae from Culebra, Porto Rico. [With M. Foslie.] Bull. Torrey Club **33**: 577-580, *pl. 23-26*. December 19, 1906.

Report on a visit to Jamaica for collecting marine algae. Jour. N. Y. Bot. Gard. **8**: 51-60, *f. 9-14*. March, 1907.

[Review of] Gardner's Cytological studies in *Cyanophyceae*. Torreya **7**: 104, 105. May 20, 1907.

Phycological studies.—III. Further notes on *Halimeda* and *Avrainvillea*. Bull. Torrey Club **34**: 491-516, *pl. 25-30*. December 17, 1907.

Lucien Marcus Underwood: a memorial tribute. Bull. Torrey Club **35**: 13-16. February 29, 1908.

[Review of] Cole's Bermuda in periodical literature. Torreya **8**: 56, 57. March 27, 1908.

Report on the botanical exploration of the Bahama and Caicos Islands. (With Percy Wilson.) Jour. N. Y. Bot. Gard. **9**: 41-50, *f. 9-12*. March, 1908.

The collections of algae. Jour. N. Y. Bot. Gard. **9**: 123-130, *pl. 46* + *f. 17-21*. July, 1908.

[Review of] Thaxter's Contribution toward a monograph of the *Laboulbeniaceae*. Torreya **9**: 6-8. January 26, 1909.

[Review of] Recent bulletins of the State Geological and Natural History Survey of Connecticut. Torreya **9**: 35-57. February 26, 1909.

Phycological studies.—IV. The genus *Neomeris* and notes on other *Siphonales*. Bull. Torrey Club **36**: 75-104, *pl. 1-8*. March 4, 1909.

Report on an expedition to Jamaica, Cuba, and the Florida Keys. Jour. N. Y. Bot. Gard. **10**: 115-118. May, 1909.

[Review of] Jepson's A flora of California. Torreya **10**: 16-18. January 29, 1910.

Report on a botanical visit to the Isthmus of Panama. Jour. N. Y. Bot. Gard. **11**: 30-44, *f. 7-15*. February, 1910.

Editorial note, *in* E. I. Thompson. The morphology of *Taenioma*. Bull. Torrey Club **37**: 98. March 31, 1910.

Charles Reid Barnes. Bryologist **13**: 66, 67. May 2, 1910.

[Review of] Greene's Landmarks of botanical history. Torreya **10**: 149-156. August 1, 1910.

[Review of] Collins' The green algae of North America. Torreya **10**: 188, 189. August 29, 1910.

A little-known mangrove of Panama. Jour. N. Y. Bot. Gard. **12**: 61-72, *f. 16-23*. April, 1911.

[Review of] Gepps' The *Codiaceae* of the Siboga Expedition. Torreya **11**: 133-137. June 19, 1911.

[Review of] Some recent University of California publications. Torreya **11**: 176-180. August 14, 1911.

The plant photograph exhibit. Jour. N. Y. Bot. Gard. **12**: 218-230. October, 1911.

Phycological studies.—V. Some marine algae of Lower California, Mexico. Bull. Torrey Club **38**: 489-514, *pl. 27-34* + *f. 1*. December 1, 1911.

Reef-building and land-forming seaweeds. Proc. Acad. Nat. Sci. Philadelphia **64**: 137, 138. March, 1912. [Reprinted in] Bot. Jour. **2**: 66. August, 1912.

The building of "coral" reefs. Science II. **35**: 837-842. May 31, 1912.

[Review of] Fertilizer resources of the United States [Senate Document, No. 190]. Torreya **13**: 220-223. September 2, 1913.

Two recent works on the marine algae. Torreya **14**: 4-8. January 27, 1914. [Review.]

The marine algae of Peru. Science II. **39**: 254. February 13, 1914. [Abstract.]

Report on a collecting trip to Georgia and Florida. Jour. N. Y. Bot. Gard. **15**: 60-63. March, 1914.

Some midwinter algae of Long Island Sound. Torreya **14**: 97-101. June 8, 1914.

The marine algae of Peru. Mem. Torrey Club **15**: 1-185, *pl. 1-66* + *f. 1-44*. September 19, 1914.

Oxymitra (*Tessellina*) in the United States. Bryologist **17**: 72-75, *f. 1*. October 14, 1914.

Further observations on the Texan *Oxymitra* (*Tessellina*). Bryologist **17**: 92-94. November 24, 1914.

[Review of] The marine algae of the Danish West Indies. Torreya **15**: 46-50. April 15, 1915.

Ricciaceae [of Mona Island]. Ann. Missouri Bot. Gard. **2**: 50, 51. May, 1915.

[Review of] Setchell, The *Scinaia* assemblage. Torreya **15**: 134-136. July 16, 1915.

The twentieth anniversary celebration of The New York Botanical Garden. Jour. N. Y. Bot. Gard. **16**: 203-219, *pl. 163*. November 2, 1915.

Report on a visit to Porto Rico for collecting marine algae. Jour. N. Y. Bot. Gard. **16**: 219-225. November 2, 1915.

Algae [of Palmyra Island]. [With H. L. Lyon.] College of Hawaii Publ. Bull. **No. 4**: 31, 32. April 19, 1916.

Notes on species of *Halymenia*. [With F. S. Collins.] Bull. Torrey Club **43**: 169-182. May 20, 1916.

Notes on some marine algae from the vicinity of Beaufort, North Carolina. [With W. D. Hoyt.] Mem. N. Y. Bot. Gard. **6**: 105-123, *pl. 11-15*. August 31, 1916.

A note on the structural dimorphism of sexual and tetrasporic plants of *Galaxaura obtusata*. Bull. Torrey Club **43**: 621-624. January 10, 1917.

Some economic uses and possibilities of the seaweeds. Jour. N. Y. Bot. Gard. **18**: *1-15*. January, 1917. [Reprinted in abridged form in] Scientific American Suppl. **83** (no. 2148): 134, 135. March 3, 1917.

[Review of] Grout's Moss flora of New York City and vicinity. Torreya **17**: 67. May 10, 1917.

Notes on North American species of *Riccia*. Bryologist **20**: 33-37, *pl. 3*. May 29, 1917.

[Review of] Fritsch's The algal ancestry of the higher plants. Torreya **17**: 123-127. July 18, 1917.

Algae. *In* N. L. Britton, Flora of Bermuda, 489-540. February 28, 1918.

The marine algae and marine spermatophytes of the Tomas Barrera Expedition to Cuba. Smithsonian Misc. Coll. **68**[11]: 1-13. April 9, 1918. [Illust.]

Algae [of the American Virgin Islands; bibliography]. Brooklyn Bot. Gard. Mem. **1**: 116, 117. July 6, 1918.

Further notes on the structural dimorphism of sexual and tetrasporic plants in the genus *Galaxaura*. Brooklyn Bot. Gard. Mem. **1**: 191-197, *pl. 3, 4* + *f. 1-4*. July 6, 1918.

Calcereous algae from Murray Island, Australia, and Cocos-Keeling Islands. Carnegie Inst. Washington Publ. **213**: 291-296, *pl. 97, f. 2; pl. 98*. August 16, 1918.

The new dahlia border. Jour. N. Y. Bot. Gard. **19**: 185-192. August, 1918.

The dahlia border. Jour. N. Y. Bot. Gard. **19**: 291, 292. November, 1918.

Dahlias and their culture. Jour. Hort. Soc. N. Y. **2**: 285-301, *pl. 45* + *f. 1-3*. February, 1919. [Reprinted in abridged and modified form in] Gardeners' Chronicle (of America) **23**: 152-154. May, 1919.

On some fossil and recent *Lithothamnieae* of the Panama Canal Zone. U. S. Nat. Mus. Bull. **103**: 1-13, *pl. 1-11*. February 19, 1919.

Tertiary calcareous algae from the islands of St. Bartholomew, Antigua, and Anguilla. Carnegie Inst. Washington Publ. **291**: 9-19, *pl. 1-6*. October 17, 1919.

Observations on monosporangial discs in the genus *Liagora*. Bull. Torrey Club **47**: 1-8, *pl. 1* + *f. 25-29*. February 18, 1920.

Ricciaceae. In N. L. Britton, and C. F. Millspaugh, The Bahama flora. 502, 503. June 26, 1920.

Algae. In N. L. Britton, and C. F. Millspaugh, The Bahama flora. 553-618. June 26, 1920.

The marine algae of the Bahamas. Jour. N. Y. Bot. Gard. **21**: 97, 98. May, 1920. [Abstract.]

Some plants from tropical sea gardens. Natural History **20**: 560-568. 1921. [Illust.]

A new species of *Laurencia* from Chile, described by De-Toni, Forti, and Howe: *Laurencia chilensis* sp. nov. [De-Toni, Forti, and Howe]. Nuov. Notar. **32**: 150-153, *f. 1-3*. [June] 1921. [The English part, excepting title, by Howe.]

The "working" of Long Lake. Jour. N. Y. Bot. Gard. **22**: 156-159. August, 1921.

The Collins collection of algae. Jour. N. Y. Bot. Gard. **23**: 23, 24. February, 1922.

Dahlia "Dahliadel Century." Addisonia **6**: 49, 50, *pl. 217*. March 9, 1922.

Dahlia "Ami Nonin." Addisonia **6**: 51, 52, *pl. 218*. March 9, 1922.

Dahlia "Mme. J. Coissard." Addisonia **6**: 53, 54, *pl. 219*, March 9, 1922.

Dahlia "Marguerite Clark." Addisonia **6**: 55, 56, *pl. 220*. March 9, 1922.

Dahlia "Miss Nannie B. Moor." Addisonia **6**: 57, 58, *pl. 221*. March 9, 1922.

Dahlia "King of the Autumn." Addisonia **6**: 59, 60, *pl. 222*. March 9, 1922.

Dahlia "W. W. Rawson." Addisonia **6**: 61, 62, *pl. 223*. March 9, 1922.

Dahlia "Douglas Tucker." Addisonia **6**: 63, 64, *pl. 224*. March 9, 1922.

The leaf hopper as an enemy of the dahlia. Bull. Am. Dahlia Soc. **3**: 19, 26. 1922.

Spray for dahlias. Bull. Am. Dahlia Soc. **3**: 18. 1922. [Written as final part of preceding article, but dislocated and given separate title by editor.]

The Amateur's Book of the Dahlia. Bull. Gard. Club Am. No. 5 (new series) 300, 301. May, 1922. [Review of book by Mrs. Charles H. Stout.]

A new American fossil hepatic. [With Arthur Hollick.] Bull. Torrey Club **49**: 207-209, *f. 1.* August 10, 1922.

Looking over the season's dahlias. Gard. Mag. **36**: 200-202. 1922. [Illust.]

Two new *Lithothamnieae,* calcareous algae, from the Lower Miocene of Trinidad, British West Indies. Proc. U. S. Nat. Mus. **62**[7]: 1-3, *pl. 1-4.* December 22, 1922.

Order *Sphaerocarpales.* [With Caroline Coventry Haynes.] North Am. Fl. **14**: 2. January 19, 1923.

Sphaerocarpaceae. [With Caroline Coventry Haynes.] North Am. Fl. **14**: 3-6. January 19, 1923.

Riellaceae. [With Caroline Coventry Haynes.] North Am. Fl. **14**: 7, 8. January 19, 1923.

Ricciaceae. North Am. Fl. **14**: 11-27. January 19, 1923.

Dahlias and their culture. Jour. N. Y. Bot. Gard. **24**: 169-187. September, 1923. [Illust.] [Reprinted in] Flower Grower **11**: 129-131. April, 1924; 172-174. May, 1924. [Illust.]

Botany of Porto Rico and the Virgin Islands. Jour. N. Y. Bot. Gard. **24**: 188, 189. September, 1923. [Review of work by N. L. Britton and P. Wilson.]

Tropical ferns. Jour. N. Y. Bot. Gard. **25**: 37, 38. March 6, 1924. [Lecture abstract.]

Chinese marine algae. Bull. Torrey Club **51**: 133-144, *pl. 1-2.* May 17, 1924.

Starch-bearing plants. Jour. N. Y. Bot. Gard. **25**: 135-142. May, 1924. [Lecture abstract.]

Roses and their culture. Jour. N. Y. Bot. Gard. **25**: 226-228. August, 1924. [Lecture abstract.]

Notes on algae of Bermuda and the Bahamas. Bull. Torrey Club **51**: 351-359, *f. 1-14.* August 22, 1924.

Spring-flowering bulbs and how to force them for the home. Jour. N. Y. Bot. Gard. **25**: 251-253. September, 1924. [Lecture abstract.]

The 1924 dahlia collection. Jour. N. Y. Bot. Gard. **25**: 255-257. September, 1924.

Growing quality dahlias. Horticulture n. s. **3**: 502. October 1, 1924.

The 1924 dahlia season. Jour. N. Y. Bot. Gard. **25**: 317, 318, *pl. 300.* Issue for December, 1924 [January, 1925].

Hepaticae. In A. J. Grout, Mosses with a Hand-lens, 225-303. January, 1925. [3rd Ed.] [Pages 235-250, 257, 258, 269-272, written by M. A. H., and the other pages more or less revised, from Grout's text in second edition.]

Ezra Brainerd. Jour. N. Y. Bot. Gard. **26**: 12, 13. January, 1925.

Dahlias and their culture. Year Book [Fed. Gard. Clubs N. Y. State] **1925**: 13. February 17, 1925.

Dahlias and their cultivation. Year Book Mass. Hort. Soc. **1925**: 83-96. 1925.

[Review] Curtis's "A Guide to the Trees." Torreya **25**: 61. July 2, 1925.

Lithothamnium (?) *ellisianum* sp. nov. from the Jurassic Ellis formation of Montana. [With Marcus I. Goldman.] Am. Jour. Sci. V. **10**: 314-324, *f. 1-11*. October, 1925.

So-called stunt in dahlias. Bull. Am. Dahlia Soc. 6^{34}: 22. October, 1925.

The name "Dahlia." Bull. Am. Dahlia Soc. 7^{35}: 12, 13. January, 1926.

Dahlia imperialis. Addisonia **10**: 49, 50, *pl. 345*. April 8, 1926.

Reef-building and land-forming plants. Jour. N. Y. Bot. Gard. **27**: 232-234. October, 1926.

A visit from Dr. Arthur W. Hill. Jour. N. Y. Bot. Gard. **27**: 243-245. November, 1926.

The 1926 dahlia collection. Jour. N. Y. Bot. Gard. **27**: 252-254, *f. 1, 2*. November, 1926.

"How Dr. Howe does it." Bull. Am. Dahlia Soc. 7^{39}: 43-45. January, 1927.

The dahlia border at The New York Botanical Garden. Off. Bull. Dahlia Soc. New England 4^{4}: 11-14. January, 1927.

The retirement of Mr. Broomall. Off. Bull. Dahlia Soc. New England 4^{5}: 13, 14. August, 1927.

Report upon a collection of marine algae made in Hudson Bay. Report of Canadian Arctic Expedition 1913-18. **4**: Botany B. 18-30, *pl. 2*. November 24, 1927.

Annie Lorenz. Torreya **28**: 11-13. February 23, 1928.

Notes on some marine algae from Brazil and Barbados. Jour. Washington Acad. Sci. **18**: 186-194, *f. 1, 2*. April 4, 1928.

Doctor Small's coöperation with Mr. Edison. Jour. N. Y. Bot. Gard. **29**: 92, 93, *f. 4*. April, 1928.

The Mrs. A. Sherman Hoyt collection of living desert plants. Jour. N. Y. Bot. Gard. **29**: 108-111, *f. 1, 2*. May, 1928.

Ornamental plants of the sea. Jour. N. Y. Bot. Gard. **29**: 136, 137. June, 1928.

The 1928 dahlia collection. Jour. N. Y. Bot. Gard. **29**: 211, 212. August, 1928.

Joseph Edward Kirkwood. Jour. N. Y. Bot. Gard. **29**: 266, 267. October, 1928.

Edward Sandford Burgess (1855-1928). Bull. Torrey Club **55**: 433-440, *portrait.* December 4, 1928. [Reprinted in] Edward Sandford Burgess [biography] 4-10. 1932.

Horticultural and educational features of The New York Botanical Garden. Year Book Fed. Gard. Clubs N. Y. State **5**: 17, 18. 1929.

New York's first botanical garden. Jour. N. Y. Bot. Gard. **30**: 49-58, *f. 1, 2.* March, 1929.

Two new species of *Chara* from tropical America. Field Mus. Nat. Hist. Bot. **4**: 159-161, *pl. 16.* July 5, 1929.

[Remarks in symposium on plant nomenclature.] Proc. Internat. Congr. Pl. Sci. **2**: 1561-1564. 1929.

The resignation of Dr. Nathaniel Lord Britton as Director-in-Chief of The New York Botanical Garden. Jour. N. Y. Bot. Gard. **31**: 1-6, *pl. 305.* January, 1930.

Doctor Elmer Drew Merrill, the new Director-in-Chief. Jour. N. Y. Bot. Gard. **31**: 6-10. January, 1930. [Illust.]

Dahlia Maxonii. Addisonia **14**: 63, 64, *pl. 480.* February 28, 1930.

The alphabetical iris check list. Jour. N. Y. Bot. Gard. **31**: 100-101. April, 1930. [Review.]

Report of the acting Director-in-Chief [for 1930]. Bull. N. Y. Bot. Gard. **14**: 167-173. May 3, 1930.

Dahlias are plants of American origin. Arts and Decoration **33**: 64, 65, 96, 98. September, 1930. [Illust.] [Reprinted in] Bull. Am. Dahlia Soc. **12**: 4-7. January, 1931. [Illust.]

Beauty pays. [Editorial] Westchester County Times. February 20 and 27, 1931.

Notes on new or little-known marine algae from Brazil. [With W. R. Taylor.] Brittonia **1**: 7-33, *pl. 1, 2* + *f. 1-11a.* February 28, 1931.

Botanical exploration of the island of Hainan. Jour. N. Y. Bot. Gard. **32**: 45, 46. February, 1931.

A new travertine-forming organism. Science II. **73**: 508. May 8, 1931. [Abstract.]

Pruning and disbudding dahlias. Home Acres [no vol.] 6. May, 1931; [same in] Westchester Magazine [no vol.] 6. May, 1931.

Notes on the algae of Uruguay. Bull. Torrey Club **57**: 605-610, *pl. 37.* October 15, 1931.

Marine algae from the islands of Panay and Negros (Philippines) and Niuafoou (between Samoa and Fiji). Jour. Washington Acad. Sci. **22**: 167-170, *f. 1.* April 4, 1932.

Preface [to P. A. Rydberg, Flora of the prairies and plains of central North America. New York. April 14, 1932.]

Chlorotylites, a fossil green alga from Alabama. Bull. Torrey Club **59**: 219, 220, *pl. 15.* May 4, 1932.

[Review of] Newton's A hand book of the British seaweeds. Torreya **32**: 73, 74. June 10, 1932.

New York dahlias thrive in Ethiopia. Jour. N. Y. Bot. Gard. **33**: 126-129, *f. 1.* June, 1932.

The geologic importance of the lime-secreting algae, with a description of a new travertine-forming organism. U. S. Geol. Survey Prof. Paper **170**: 57-64, *pl. 19-23.* July 27, 1932.

Winter storage of dahlias. New York Gardens **1**: 81-83. October, 1932.

Plants that form reefs and islands. Sci. Monthly **36**: 549-552. June, 1933.

A blue-green alga of carbonated mineral water. Bull. Torrey Club **60**: 465-468, *pl. 24, 25.* October 2, 1933.

Arthur Hollick: February 6, 1857-March 11, 1933. Bull. Torrey Club **60**: 537-553, *portrait.* November 1, 1933.

The 1933 dahlia collection. Jour. N. Y. Bot. Gard. **34**: 250. November, 1933.

Annual report, A[merican] D[ahlia] S[ociety] nomenclature committee. Bull. Am. Dahlia Soc. **9**: 15. November, 1933.

The dahlia border at the Bronx. [The 1933 dahlia border at The New York Botanical Garden.] Bull. Am. Dahlia Soc. **9**: 27. November, 1933.

Hawaiian algae collected by Dr. Paul C. Galtsoff. Jour. Washington Acad. Sci. **24**: 32-42, *f. 1-5.* January 15, 1934.

On small dahlia classifications. Bull. Am. Dahlia Soc. **10**: 24, 25. February, 1934.

Let's settle borderline variety question by popular vote. Bull. Am. Dahlia Soc. **10**(48): 10. May, 1934.

Tree dahlias. Bull. Am. Dahlia Soc. **10**(48): 15. May, 1934.

Elizabeth Gertrude Britton. Jour. N. Y. Bot. Gard. **35**: 97-103. May, 1934. [Illust.]

Eocene marine algae (Lithothamnieae) from the Sierra Blanca limestone. Bull. Geol. Soc. Am. **45**: 507-518, *pl. 52-56.* June 30, 1934.

Elizabeth Gertrude Britton. Wild Flower **11**: 26. July 1, 1934. [Reprinted in] Desert Plant Life **6**: 35, 43. July, 1934.

Nathaniel Lord Britton. Jour. N. Y. Bot. Gard. **35**: 169-180, *portrait.* August, 1934.

A new daylily book. Torreya **34**: 97, 98. 1934. [Review of A. B. Stout's "Daylilies".]

"The Families of Flowering Plants." Garden Digest **6** (9): 41, 42. October, 1934. [Review of two-volume work by J. Hutchinson.]

Some marine algae of the Shantung Peninsula. Lingnan Sci. Jour. **13**: 667-670. *f. 1.* October 1, 1934.

The Templeton Crocker Expedition of the California Academy of Sciences, 1932. No. 17. The *Hepaticae* (chiefly *Riccia* and *Anthoceroteae*) of the Galapagos Islands and the coast and islands of Central America and Mexico. Proc. Calif. Acad. Sci. IV. **21**: 199-208, *pl. 7.* October 26, 1934.

Looking over the newer dahlias. Flower Grower **21**: 513-515, 549. December, 1934. [Illust.]

Dahlias at The New York Botanical Garden. The Dahlia: Off. Bull. Central St. Dahlia Soc. **3**(2) : 9, 10, 24. December, 1934.

Nathaniel Lord Britton [Minutes of Board of Managers of the New York Botanical Garden and of the Council of the New York Academy of Sciences.]. Science **81** : 87, 88. January 25, 1935.

A proposed official revision of the classification of the dahlia. Bull. Am. Dahlia Soc. **10**(71) : 28, 29. February, 1935.

The earliest-known illustrations of the Dahlia. Bull. Am. Dahlia Soc. **11**(72) : 9, 10, *f. 1-4.* May, 1935.

The 1935 season at The New York Botanical Garden. Bull. Am. Dahlia Soc. **11**(74) : 26. November, 1935. [Illust.]

The 1935 dahlia border. Jour. N. Y. Bot. Gard. **36**: 283-287, *f. 1, 2.* December, 1935.

The dahlia marches on. Flower Grower **23** : 139, 140, 160. March, 1936. [Illust.]

Dahlia. The Garden Dictionary, 196-198. March, 1936.

Annual report of the Director for the year 1935. Jour. N. Y. Bot. Gard. **37** : 77-89. April, 1936.

Chaplain Joseph Clemens. Jour. N. Y. Bot. Gard. **37**: 117, 118. May, 1936.

[Review of] The Garden Dictionary. Jour. N. Y. Bot. Gard. **37** : 122, 123. May, 1936.

[Review of] Tilden's The algae and their life relations. Torreya **36**: 66-68. June 30, 1936.

H. P. Armsby

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OF

HENRY PRENTISS ARMSBY

1853–1921

BY

FRANCIS G. BENEDICT

PRESENTED TO THE ACADEMY AT THE ANNUAL MEETING, 1938

HENRY PRENTISS ARMSBY

1853–1921

BY FRANCIS G. BENEDICT

"Born of good, solid New England stock," an expression characterizing so many of America's foremost citizens, applies to Henry Prentiss Armsby, who, the only child of Lewis and Mary A. (Prentiss) Armsby, was born September 21, 1853, in Northbridge, Massachusetts. The father, a skillful cabinet maker, early moved to Whitinsville and subsequently to Millbury, Massachusetts. After receiving the usual elementary school training in these towns, Henry entered the Worcester County Free Institute of Industrial Science at the age of fifteen years. This Institute later became the Worcester Polytechnic Institute. The records show that Armsby, as a schoolboy, was "absorbed" in chemical experiments. Three years later (1871), in the first class to graduate from this Institute, he received the degree of Bachelor of Science. The following year he remained at the Institute as instructor in chemistry and then realized the objective of many years, graduate work at Yale University under the inspiration of Professor S. W. Johnson. Receipt of the degree of Bachelor of Philosophy at Yale University in 1874 was coincidental with his first scientific publications, "On the Nitrogen of the Soil" and "Experiments on the Decay of Nitrogenous Organic Substances." After a year of teaching science in the high school at Fitchburg, Massachusetts, a long-wished-for sojourn in Germany (Leipzig) followed. Here, under Gustav Kühn, in company with his close friend, E. H. Jenkins of New Haven, a most profitable year full of intense work followed. Jenkins comments on Armsby's method of work as follows:

"He was a thinker. . . . He would sit with his feet to the fire, not drowsing or dreaming, but thinking hard, and then he would go to his desk and write awhile, and then come back to think."

This habit of intense, concentrated thinking characterized the man's entire life. A snap judgment, a hunch, seemed out of his experience.

Although trained as a chemist, Armsby, in the Kühn atmosphere at Leipzig, began to take special interest in problems of physiology and from then on drifted more and more towards physiological work. This inclination culminated in his classic contributions to animal nutrition and calorimetry. Nevertheless he was destined to live a chemist's life for some time, for upon his return from Germany he taught chemistry at Rutgers College, New Brunswick, New Jersey, from 1876 to 1877.

The Agricultural Experiment Station movement began under the stimulation of Johnson and Atwater, and in 1877 Armsby was called to Connecticut to be chemist of the first Agricultural Experiment Station established in the United States. Recognizing the paucity of information in English on cattle feeding, Armsby immediately began a translation of E. v. Wolff's "Landwirtschaftliche Fütterungslehre." The changes and additions that he found necessary to bring this up to date for American conditions resulted in his first book called "Manual of cattle feeding," which was published in 1880. A year before this Yale University had granted him the degree of Doctor of Philosophy. His intense interest in animal feeding led rapidly to the publication of a series of papers on the digestion, the composition, and the utilization of feeds by domestic animals, accompanied by a number of papers on the chemistry of soil, milk, and problems dealing with the furthering of agricultural science. His two years (1881-1883) as Vice-Principal and Professor of Agricultural Chemistry at the Storrs Agricultural School (later the Connecticut Agricultural College) were somewhat in the nature of marking time, but in his appointment as Professor of Agricultural Chemistry and Associate Director and Chemist of the Agricultural Experiment Station at the University of Wisconsin in 1883 he received his first great impetus to administrative and research work. Here he remained until, in 1887, he was called to the directorship of the new Agricultural Experiment Station of Pennsylvania State College, where his great life work was to be accomplished.

The fact that his whole life was associated with institutions of agricultural research has to some extent pushed into the background the fact that his interests were far broader than even

the wide limits of the term "Agricultural Research" would imply. Chemist, physiologist, author, critic, administrator, organizer, all combined in a marvelous manner to make every undertaking an instant and permanent success. The administrative work was irksome but faithfully carried out, and it was with joy that in 1907 he was relieved in part of much routine administrative work as Director of the Pennsylvania Agricultural Experiment Station and made Director of the newly organized Institute of Animal Nutrition of Pennsylvania State College. Although his efforts in behalf of agricultural science prior to 1907 were invariably successful, it was with the new Institute that the full powers of this man developed.

Nearly ten years before, Armsby had become convinced that the true basis of animal feeding, a problem at once of deepest physiological importance and of tremendous economic significance, could best be studied by a wholly new line of attack. Food is given to keep animals alive, to provide for normal growth, to facilitate the best powers of reproduction, and, in the case of cattle, to render fit for human consumption in the shape of beef flesh or milk the fodders, forages, and grasses inedible to man. The energetics of these transformations had always intrigued him and, according to his concept, the one logical method of studying them was with an accurately measurable standard, *i. e.,* the calorie. At the Institute of Animal Nutrition, then, he began plans for that unique instrument, the great respiration calorimeter for large domestic animals. This was housed in a special building, together with most perfect accessory apparatus, and technicians were carefully trained to operate it. Naturally these heroic experiments challenged the attention of research workers in animal nutrition throughout the world. So perfect was the design, construction, and operation of this intricate apparatus that immediately Armsby began to unfold new concepts and impress practices in the highly important economic and physiological problems of animal nutrition. Similar problems had been challenging European scientists for many decades, and shortly his apparatus was duplicated by Hagemann at the Experiment Station at Bonn-Poppelsdorf. Hagemann made a number of unsuccessful "betterments" but was never able to

secure satisfactory results with the equipment, clearly due to his inability to follow well-laid rules and constructive design. A second replica was constructed in the admirable laboratory of Tangl at Budapest. Unfortunately, owing to his untimely death, this instrument was never put into successful operation. Hence today the only respiration calorimeter in which at the same time direct and indirect calorimetric measurements can be made on large domestic animals is that constructed by Armsby, which remains as his monument at State College, Pennsylvania.

Not only was his apparatus at the Institute of Animal Nutrition copied by at least two great European centers of research, but his Institute became a Mecca for a host of scientists who came to this country interested both in animal and in human nutrition, and a visit of Rockefeller Fellows or medical groups from other lands, studying human nutrition in this country, was never complete without a trip to the Armsby Institute at Pennsylvania State College.

In 1905 the Carnegie Institution of Washington commissioned Armsby to examine and report on the entire procedures of the Atwater respiration calorimeter for humans at Wesleyan University, Middletown, Connecticut, preliminary to the establishment by the Carnegie Institution of Washington of a Nutrition Laboratory in Boston. No man in America other than Armsby was even considered for this survey. His critical inspection and suggestions were all presented in a report so complete (as an engineer's report on a project) that the Nutrition Laboratory was started with the sound confidence of its success. In 1919 the Carnegie Institution of Washington again availed itself of Armsby's superior critical judgment, when, prior to the initiation of an extensive study of the basal metabolism and the energy transformations in the complex digestive system of large ruminants, Armsby was commissioned to survey critically the joint research project of the Carnegie Institution's Nutrition Laboratory and the Laboratory of Animal Nutrition (under the direction of Professor E. G. Ritzman) at the New Hampshire Agricultural Experiment Station, Durham, N. H. The project involved the then considered hazardous procedure of submitting ruminants to one or two weeks of fasting (with

water), to observe what the ruminant does with its body reserves, at how low a level of vital activity it can live, and whether upon re-feeding its original metabolic level will be resumed. As a result there was instituted simultaneously at the New Hampshire Agricultural Experiment Station and at Armsby's Institute most profitable researches on the effect of food withdrawal upon the ruminant. From this date onward there was a constant interchange of ideas between the New Hampshire Laboratory, the Nutrition Laboratory in Boston, and the Armsby Institute, all working on closely related problems. This was a striking example of cooperation, with the younger men ever seeking aid from the master. Almost the last letter penned by Armsby dealt with the numerous problems and discussions of the three laboratories. No name appears more frequently in the joint publications of the Nutrition Laboratory and the New Hampshire Agricultural Experiment Station than that of Armsby.

In view of his unique mastery of agricultural chemistry, animal husbandry, and animal nutrition, it is no wonder that his writings were and are today looked upon as authoritative. Through his writings and through his personal visits to Europe, Armsby became well known in all the centers of agricultural research, especially those dealing with animal nutrition in Europe, and no American in agricultural science was more frequently mentioned in discussions than Armsby. His second book, published in 1903, on "The Principles of Animal Nutrition" was in a sense a startling innovation for a man in an agricultural experiment station to write, for it took animal nutrition completely out of the rule-of-thumb barn manual, laid before animal husbandmen the basic principles upon which such feeding must ultimately be considered, and charted many of the guiding courses for his subsequent researches in calorimetry. Fourteen years later his book entitled "The Nutrition of Farm Animals" appeared. This book incorporates most successfully deep scientific insight into the innumerable problems in animal nutrition and a great deal of practical knowledge, which makes it an admirable basis for much agricultural nutritional teaching and likewise the basis for much research. All those interested

in animal nutrition have found a wealth of material in this most carefully prepared, comprehensive work. Concurrent with his important advice on the nutrition of man and animals at the time of the World War, there appeared his book on "The Conservation of Food Energy," which made a distinctly favorable impression. This was almost simultaneous with his appointment as a member of the Interallied Scientific Food Commission, upon which he remained until the end of the war. A posthumous book, the details of which had been carefully worked out prior to his death, was left for completion in the capable hands of the junior author, Professor C. Robert Moulton, and appeared in 1925 under the title "The Animal as a Converter of Matter and Energy. A Study of the Role of Live Stock in Food Production."

Armsby was married to Lucy Atwood Harding of Millbury, Massachusetts, on October 15, 1878.

The honors conferred on Armsby, both at home and abroad, were modestly received but invariably increased his sense of responsibility and obligation. The most outstanding of these honors were:

Doctor of Laws, University of Wisconsin, 1904
Elected member of the Royal Academy of Agriculture of Sweden, 1912
Doctor of Science, Yale University, 1920
Elected member of National Academy of Sciences, 1920
Doctor of Science, Worcester Polytechnic Institute, 1921

Armsby developed during that period when agricultural chemistry, as W. H. Jordan wittily remarked, was so looked down upon that the wife of the professor of organic chemistry occupied a distinctly higher social level than the wife of the professor of agricultural chemistry or, as it was often irreverently called, "cow chemistry." One often wondered if Armsby sensed keenly this lack of appreciation of the importance of agricultural chemistry and by his personality did all he could to overcome this injustice. When one met this gentleman his graceful, modest bearing, his courteous manner, his meticulous dress, instantly dispelled all erroneous notions of the standard of deportment and appearance of the agricultural chemist. A

striking feature of Armsby's personality was his invariably well-groomed appearance. He was a most modest man and spoke at formal or social gatherings with a delicacy of expression, a dry wit, and a charming manner that were the envy of his colleagues. Although having too few hobbies and relaxations, he enjoyed especially bridge whist, to which he applied his mathematical mind and prodigious memory to such purpose that it was commonly said that after the second hand was played he knew the location of all the remaining cards. Because of his naturally frail constitution he felt the responsibility for exercise and was the first golfer on his campus, driving the ball before him in his trips each day to and from his laboratory. His "one man golf club" remained an institution for years. A man considered by most as reserved, although by no means unapproachable, Armsby was, to those fortunate enough to be accepted as intimates, a rare personality. Full of courtesy, dignity, and charm, he became in the intimate circle an endearing personality, rich in dry humor and anecdote. At the only annual dinner (1921) of the Academy that he could attend, those who were at table with him will not forget his clever and delightful anecdotes. The writer was the only one of his "Fach" in the group, and it was interesting to note how he held the attention of those eight others, who represented different branches of science.

His appearance of reserve was undoubtedly due to the fact that he was completely absorbed in his work. There was too little of interest outside the laboratory, and although he took his civic duties seriously, always being available for university committees, an active church worker, and a senior warden in the Episcopal Church, nevertheless his first thought, after his family, was his laboratory and his science. As Director of an Agricultural Experiment Station, he owed certain duties to his constituency which he did not neglect, and the earnest of this is shown in his innumerable papers and the agricultural reports dealing with practical problems of the farmer. On the other hand, his contributions to abstract science are represented by his scholarly book on "The Principles of Animal Nutrition," his development of the unique respiration calorimeter, and the long

series of fundamentally important researches carried out with this instrument.

With almost pitiless energy he drove his research unendingly, and a familiar picture was he, returning to his home from the laboratory, often with a batch of protocols and a large slide rule under his arm. Although he had perfect confidence in the technical operation of his intricate respiration calorimeter by his highly trained associates, he personally supervised all the innumerable calculations. This of itself was an almost superhuman task, and those of us who knew him intimately often have felt that this pressure was his ultimate undoing. Shuttling between the rather inaccessible State College in Center County, Pennsylvania, and the bureaus in Washington at too frequent intervals undoubtedly was more than his frail constitution could stand, but with that spirit of service that characterized him in all his life, he was unwilling to slack any of the work. Perhaps Armsby's greatest fault was that the word "no" did not exist in his vocabulary. To refuse a request of his colleagues or fellow scientists in other institutions, or to refuse the call of service to the Government was to him unthinkable, and as a result he, with his extraordinary capacity for diplomacy, clear thinking, and wide vision, and above all his successful accomplishments, was called upon too much.

Of the innumerable expressions of appreciation of colleagues, associates, and friends, which followed his death on October 19, 1921, but two will be cited here. Professor W. H. Jordan wrote as follows:

"Armsby was a learned man in nutritional science, one of the leaders in this country, perhaps *the* leader in the nutrition of farm animals. When in Berlin in 1913 I asked Dr. N. Zuntz if the United States had any research workers in animal nutrition of equal standing with the best men in Europe. Zuntz answered immediately, 'Armsby.'"

Professor C. Robert Moulton, his collaborator in his last book, wrote as follows:

"Professor Armsby impressed me as an aristocratic gentleman and a member of the intellectual nobility. He was courteous and dignified, yet he showed a true interest in our welfare. The

operation of his laboratory required a well integrated staff with duties assigned and rehearsed, yet one did not feel that he was a cog in a machine, but an individual that was vital to the smooth working of the project. In so far as was possible he allowed his men a freedom and initiative. They were encouraged to give new ideas and suggestions concerning the work of the Institute. He was generous in his dealings with the members of the staff."

Owing to lack of space, the writer refrains from personal statements, much as he would like to make them, for Henry Prentiss Armsby will always remain as one of the rarest figures in his life.

Acknowledgments. In the preparation of this material I have been greatly aided by one of Professor Armsby's sons, H. H. Armsby, Registrar of the School of Mines and Metallurgy, University of Missouri, Rolla, Missouri, and by Professor Max Kriss of the Institute of Animal Nutrition, State College, Pennsylvania. The bibliography was kindly furnished by Dr. E. B. Forbes, Director of the Institute of Animal Nutrition, State College, Pennsylvania. Material has freely been drawn from the excellent book by Professor Thomas I. Mairs entitled "Some Pennsylvania Pioneers in Agricultural Science," published at State College, Pennsylvania, 1928.

BIBLIOGRAPHY OF HENRY PRENTISS ARMSBY

1874-1925

On the nitrogen of the soil. Proc. Am. Assoc. Adv. Sci., 1874, **23**, 80.

Experiments on the decay of nitrogenous organic substances. Am. Jour. Sci., 1874, III, **8**, 337.

Value of cottonseed meal and malt sprouts as feed for milch cows. Rpt. Wis. Expt. Station, 1874, 78.

Ueber die Einwirkung der Schwefelsäure auf phosphorsauren Kalk. Jour. Pract. Chem., 1876, **13**, 333.

On the absorption of bases by the soil. Am. Jour. Sci., 1877, III, **14**, 25.

Ueber das Absorptionsvermögen des Bodens für Basen. (Identical with previous paper.) Landw. Vers. Stat., 1877, **21**, 397.

Relations of the soil to water. Rpt. Conn. Expt. Station, 1877, 81; 1878, 83.

The sources of muscular power. Pop. Sci. Monthly, 1878, **12**, 729.

On the determination of albuminoids in hay and coarse fodders. Am. Chem. Jour., 1880, **2**, 81; Rpt. Conn. Expt. Station, 1879, 104.

Manual of cattle feeding. John Wiley & Sons, New York, 1880.

Recent progress in agricultural science. Am. Chem. Jour., 1880-81, **2**, 339, 426; 1881, **3**, 145; 1882-83, **4**, 146, 218.

Observations on the feeding of milch cows as practiced in Connecticut. Rpt. Conn. Expt. Station, 1881, 90.

The Bunsen lamp. Pop. Sci. Monthly, 1882, **20**, 378.

Farmers' Annual Handbook (with E. H. Jenkins). D. Appleton & Co., New York, 1882-3.

Agricultural Experiment Station. Pop. Sci. Monthly, 1883, **23**, 596.

Loss of nitrogen from arable soils. Science, 1884, **3**, 17.

Special manures for particular crops. Science, 1884, **4**, 76.

Field experiments in agriculture. Pop. Sci. Monthly, 1885, **26**, 831.

Comparative value of old and new process bran. Rpt. Wis. Expt. Station, 1885, 86.

Value of new process oil meal compared with corn meal for milk production. Rpt. Wis. Expt. Station, 1885, 97.

The Cooley system of creaming milk. Rpt. Wis. Expt. Station, 1885, 118; Proc. Soc. Promotion Agric. Sci., 1884, 49.

Ueber Aufrahmung mittelst des Cooleyschen Verfahrens. Forschungen a. d. Gebiete der Vieh-haltung, Heft 17, 1. (Identical with previous paper.)

Relation of fat of milk to butter yield. Rpt. Wis. Expt. Station, 1885, 122.

Digestion experiments. Am. Jour. Sci., 1885, **29**, 355.

Apparatus for Kjeldahl's method of nitrogen determination (with F. G. Short). Am. Chem. Jour., 1886, **8**, 323.

Nitrification. Pop. Sci. Monthly, 1886, **29**, 831.

Feeding value of roller bran. Rpt. Wis. Expt. Station, 1886, 113.

Influence of the nutritive ratio on milk production. Rpt. Wis. Expt. Station, 1886, 147.

Analyses of milk of different breeds of cows. Rpt. Wis. Expt. Station, 1886, 159.

Tests of dairy cows at Wisconsin State Fair. Wis. Expt. Station, Bull. 10, 1886.

Oleomargarine. Science, 1886, **7**, 471.

On the digestibility of maize stover (with Wm. Frear). Agric. Sci., 1888, **2**, 149; Rpt. Penna. Expt. Station, 1887, 144.

Comparative value of different forms of phosphoric acid. Rpt. Penna. Expt. Station, 1887, 69; 1888, 124.

Feeding standards and composition of feeding stuffs. Rpt. Penna. Expt. Station, 1888, 47; 1889, 42; 1890, 19; 1893, 13.

The nitrogen supply of maize (with Wm. Frear). Proc. Soc. Promotion Agric. Sci., 1889, 33; Rpt. Penna. Expt. Station, 1889, 195.

The soiling system for milch cows (with Wm. Frear, H. J. Patterson, G. L. Holter, and W. H. Caldwell). Agric. Sci., 1889, **3**, 283, 325; Rpt. Penna. Expt. Station, 1888, 54.

Comparison of ensilage and field-curing for maize (with W. H. Caldwell). Agric. Sci., 1890, **4**, 119; Rpt. Penna. Expt. Station, 1889, 113.

The soiling system for milch cows (with W. H. Caldwell and G. L. Holter). Agric. Sci., 1891, **5**, 1, 39; Rpt. Penna. Expt. Station, 1889, 53.

Influence of the nutritive ratio on milk production. Proc. Soc. Promotion Agric. Sci., 1890, 11.

Ensilage of the corn crop (with Wm. Frear and W. H. Caldwell). Rpt. Penna. Expt. Station, 1890, 43.

Influence of variety and rate of seeding on yield of ensilage corn. Rpt. Penna. Expt. Station, 1891, 17.

Influence of variety and rate of seeding on the yield of soiling corn. Rpt. Penna. Expt. Station, 1891, 36.

Sampling corn fodder. Rpt. Penna. Expt. Station, 1891, 32.

Digestion experiments—Recent work abroad. U. S. Dept. Agric., Office Expt. Stations, Misc. Bull. 3, 1891, 132.

Is it desirable to affix a valuation to feeding stuffs? Agric. Sci., 1892, **6**, 118.

Variations in the composition of forage corn. Agric. Sci., 1892, **6**, 160.

Influence of ensilage and field-curing on the digestibility of forage corn. Agric. Sci., 1892, **6**, 349; Rpt. Penna. Expt. Station, 1892, 14.

The food yield of forage corn. Rpt. Penna. Expt. Station, 1892, 22.

Tests of dairy apparatus (with H. J. Waters and W. H. Caldwell). Rpt. Penna. Expt. Station, 1892, 51.

The Koch test for tuberculosis. Rpt. Penna. Expt. Station, 1892, 94.

The aim and methods of investigations in stock feeding. Agric. Sci., 1893, **7**, 481.

Tests of cream separators (with W. H. Caldwell and L. E. Reber). Rpt. Penna. Expt. Station, 1894, 13.
Cottonseed meal for dairy cows (with E. H. Hess). Rpt. Penna. Expt. Station, 1894, 44.
Rational stock feeding. Rpt. Penna. Expt. Station, 1894, 36; 1895, 16.
The computation of rations for farm animals. Rpt. Penna. Expt. Station, 1896, 18; 1897, 17.
Dried brewers' grains. Rpt. Penna. Expt. Station, 1896, 53.
A soil test with fertilizers. Rpt. Penna. Expt. Station, 1896, 123.
The maintenance ration of cattle. Rpt. Penna. Expt. Station, 1897, 65, 159, and Penna. Expt. Station Bull. 42, 1898, 188 pp.
The sugar beet in Pennsylvania. Rpt. Penna. Expt. Station, 1897, 101.
Tests of the sugar beet in Pennsylvania (with E. H. Hess). Rpt. Penna. Expt. Station, 1898-99, 80.
The available energy of timothy hay (with J. August Fries). Preliminary Report. Proc. Soc. Promotion Agric. Sci., 1902; Rpt. Penna. Expt. Station, 1901-2, 284.
The available energy of timothy hay (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 51, 1903, 77 pp.; Rpt. Penna. Expt. Station, 1902-3, 96.
Die nutzbare Energie des Timothyheues (with J. August Fries). Landw. Jahrbücher, 1904, **33**, 665. (Identical with previous paper.)
The principles of animal nutrition. John Wiley & Sons, New York, 1903.
The isodynamic replacement of nutrients. Science, 1903, **18**, 481.
The respiration calorimeter at the Pennsylvania State College. Expt. Station Rec., 1904, **15**, 1037; Rpt. Penna. Expt. Station, 1903-4, 208.
Heat values and food values. Arch. Pediat., Feb. 1905.
Relative values of feeding stuffs. Penna. Expt. Station, Bull. 71, 1905; revised ed., 1907, 16 pp.
Energy values of red clover hay and maize meal (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 74, 1905, 64 pp.; Rpt. Penna. Expt. Station, 1904-5, 124.
Energiewerte des roten Kleeheues und des Maisschrots (with J. August Fries). Landw. Jahrbücher, 1905, **34**, 861. (Identical with above.)
Dried distillers' grains vs. cottonseed meal as a source of protein (with A. K. Risser). Penna. Expt. Station, Bull. 73, 1905.
The promotion of agricultural science. Presidential address. Proc. Soc. Promotion Agric. Sci., 1906, 7-20; Science, 1906, **24**, 673.
Investigations in animal nutrition. U. S. Dept. Agric., Bureau Animal Industry, 23d Ann. Rpt., 1906, 263.
Problems of animal nutrition. Expt. Station Record, 1907, **18**, 508-521.
Research as a career. Presidential address. Proc. Soc. Promotion Agric. Sci., 1907, 9-26.
A suggestion for a new unit of energy. Proc. Soc. Promotion Agric. Sci., 1907, 28, 164-7; Science, 1907, **26**, 670-672.
Feed as a source of energy. Penna. Expt. Station, Bull. 84, 1907, 16 pp.

The available energy of red clover hay (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 101, 1908, 61 pp.; Rpt. Penna. Expt. Station, 1906-7, 94.

Feeding for meat production. U. S. Dept. Agric., Bureau Animal Industry, Bull. 108, 1908, 89 pp.

The computation of rations for farm animals by the use of energy values. U. S. Dept. Agric., Farmers' Bull. 346, 1909.

Principles of stock feeding. Cyclopaedia of American Agriculture. Macmillan Co., New York, 1907-9.

The food supply of the future. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1909, pub. Jan. 1910; Science, 1910, **30**, 817-823.

Essentials in the training of the investigator. Proc. Soc. Promotion Agric. Sci., 1910, 113-119.

The respiration calorimeter at the Institute of Animal Nutrition of the Pennsylvania State College. Penna. Expt. Station, Bull. 104, 1910, 16 pp.; II Congrès International d'Hygiène Alimentaire, vol. 1, Sect. 1, p. 45.

The influence of type and of age upon the utilization of feed by cattle (with J. August Fries). U. S. Dept. Agric., Bureau Animal Industry, Bull. 128, 1911, 245 pp.; Penna. Expt. Station, Bull. 105, 1910, 22 pp.

The nutritive value of the non-protein of feeding stuffs. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1910, pub. June 1911.

The nutritive value of the non-protein of feeding stuffs. U. S. Dept. Agric., Bureau Animal Industry, Bull. 139, 1911, 49 pp.

The maintenance ration of cattle. Penna. Expt. Station, Bull. 111, 1911, 20 pp.

The conservation of the food supply. Pop. Sci. Monthly, Nov. 1911, 6 pp.

The maintenance rations of farm animals. U. S. Dept. Agric., Bureau Animal Industry, Bull. 143, 1912, 110 pp.

Some unsolved problems. Presidential address. Am. Soc. Animal Nutr., Proc. Ann. Meeting, Nov. 1911, pub. Jan. 1912.

The influence of standing or lying upon the metabolism of cattle (with J. August Fries). Am. Jour. Physiol., 1913, **31**, 245-253.

The same: Eighth International Congress of Applied Chemistry, 1913, **15**, 23-33.

A comparison of the observed and computed heat production of cattle. Jour. Am. Chem. Soc., 1913, **35**, 1794-1800.

Food as body fuel. Penna. Expt. Station, Bull. 126, 1913, 68 pp.

Net energy values of feeding stuffs for cattle (with J. August Fries). Jour. Agric. Research, 1915, **3**, 435-491.

Net energy values for ruminants (with J. August Fries). Penna. Expt. Station, Bull. 142, 1916, 3-14.

Net energy values of American feeding stuffs (with F. S. Putney). Penna. Expt. Station, Bull. 142, 1916, 15-20.

Computation of dairy rations (with F. S. Putney). Penna. Expt. Station, Bull. 143, 1916, 3-24.

Energy values of red clover hay and maize meal (with J. August Fries and W. W. Braman). Jour. Agric. Research, 1916, 7, 379-387.

The use of energy values in the computation of rations for farm animals. U. S. Dept. Agric., Bureau Animal Industry, Bull. 459, 1916, 31 pp.

The nutrition of farm animals. Macmillan Co., New York, 1917.

Energy values of hominy feed and maize meal for cattle (with J. August Fries). Jour. Agric. Research, 1917, 10, 599-613.

Influence of the degree of fatness of cattle upon their utilization of feed (with J. August Fries). Jour. Agric. Research, 1917, 11, 451-472.

Basal katabolism of cattle and other species (with J. August Fries and W. W. Braman). Jour. Agric. Research, 1918, 13, 43-57; prelim. rpt., Proc. Nat. Acad. Sci., 1918, 4, 1-4.

The conservation of food energy. W. B. Saunders Co., Philadelphia, July, 1918.

Net energy values of alfalfa hay and of starch (with J. August Fries). Jour. Agric. Research, 1918, 15, 269-286.

Net energy values and starch values (with J. August Fries). Jour. Agric. Sci., 1919, 9, 182-187.

The organization of research. Address before Section M, Am. Assoc. Adv. Sci., St. Louis, 1919; Science, 1919, 51, 33-38.

A national institute of nutrition. Science, 1919, 50, 242-244.

The modern science of food values. Yale Review, 1920, 9, 330-345.

The carbon dioxide: heat ratio in cattle (with J. August Fries and W. W. Braman). Proc. Nat. Acad. Sci., 1920, 6, 263-265.

Cooperative experiments upon the protein requirements for the growth of cattle. First report of the Subcommittee on Protein Metabolism in Animal Feeding. Nat. Research Council, Bull. 12, 1921, 219-288.

Some fundamentals of stable ventilation (with Max Kriss). Jour. Agric. Research, 1921, 21, 343-368.

The animal as a converter of matter and energy (with C. Robert Moulton). Chemical Catalogue Co., New York, 1925.

Harris J. Ryan

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OF

HARRIS JOSEPH RYAN

1866–1934

BY

W. F. DURAND

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HARRIS JOSEPH RYAN

1866–1934

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The family of Professor Harris Joseph Ryan on his father's side traces back to pre-revolutionary Irish stock in the person of an enterprising lad who, sometime perhaps about the middle of the eighteenth century, came to this country and took up land in Pennsylvania, married and finally settled down in what later became the little town of Matamoras (post office, Powells Valley). The family flourished, and some three or four generations later, on January 8, 1866, there was born to Charles W. and Louisa M. (Collier) Ryan, a son who was christened Harris Joseph. On the mother's side, the Colliers traced back to early Scottish stock which, intermarrying with the German and other early Pennsylvania stocks, furnished much of the sturdy backbone of the rural population in east central Pennsylvania as found there during the nineteenth century.

When Ryan was still a small boy, his father moved from the farm in Matamoras to Halifax where he had interests in lime kilns and later became cashier of the Halifax National Bank, which position he retained until his death in 1901.

Ryan's first schooling was in a country school in Matamoras, following which he passed a few years in the schools of Halifax, and later in a school at Mt. Airy, Philadelphia. These earlier periods of schooling covered what would now be called the "grades," following which he covered the requirements for college entrance, partly at the Baltimore City College and partly at the Lebanon Valley College.

It is always fascinating to speculate on what might have been the future career of a man of mark if, when at some crossroads of life, he had taken a turning different from that actually followed. So here, the natural turn for young Ryan, with college preparatory in Baltimore and vicinity, would have been to plan ultimately for Johns Hopkins (then a post graduate institution only) and this would presumably have been the course followed

but for an accidental meeting with an enthusiastic young student from Cornell at home on a vacation.

The picture of life at Cornell and of the opportunities to be found there proved so alluring to young Ryan that all other plans were put aside and he entered Cornell in 1883.

His interest in science had early begun to appear. There is extant in the family a story of demonstrations which, as a school boy, he carried on with a miniature chemical outfit which his father had given him, much to the interest and wonder of friends and relatives.

There was growing interest likewise in the field of physics, or "natural philosophy" as it was then often called, and with increasing maturity, especially in the domain of electricity which, in the early eighties was just beginning to give some faint indications of the part it was soon to play in our modern civilization. With these trends of interest, it was only natural that at Cornell, his immediate objective would be the course in electrical engineering just at that time announced in the Department of Physics under Prof. Wm. A. Anthony.

In 1926, on the occasion of the award of the Edison Medal to Professor Ryan, referring in his response to this period of his life he said:

"Forty-three years ago this fall I entered Cornell as a freshman to take up the curriculum in electrical engineering, that had just been established and for which students were being admitted for the first time. The electrical engineering laboratory of the University was little more than the electrical section of the physics laboratory of that day. The little more was one direct-current generator invariably referred to as the Gramme dynamo that was built by Professor Wm. A. Anthony, the 1890-1891 President of the Institute.

"Professor Anthony visited France immediately after 1872 when Gramme had completed his direct-current generator, generally conceded to have been the first direct-current dynamo of size adequate to reveal its possibilities in the engineering industries. Professor Anthony visited Gramme, saw his generator, and on returning to Cornell immediately set about to construct a replica thereof. It was completed in 1874 and exhibited just a half century ago at the Centennial in Philadelphia. Curricula in electrical engineering at Columbia, Cornell and other uni-

versities were announced somewhat less than ten years after the Centennial."

In this way the young student Ryan came under the stimulating leadership of Professor Anthony, who, perhaps more than any other of his teachers, exercised a guiding influence into and along the lines of work which later became his chief life interest.

In this connection a letter which he wrote to Mr. F. J. Sprague under date of June 7, 1932, on the occasion of a birthday dinner to Sprague in New York City, is likewise of interest. In this letter he recalls a visit made by Professor Anthony to the Sprague Works in New York in the winter of 1886-87 with a small group of his students, among whom he (Ryan) was present. He then recalls to Sprague that, in the conversation between himself and Anthony, he (Sprague) said in substance, "In my studies I have found that economy in the electrical transmission of power will be directly proportional to the voltage and inversely proportional to the distance." And then continues Ryan to Sprague, "Thus this started me out in life with a never ending enthusiasm for the study of high voltage phenomena."

The Cornell of 1883 was an institution of only slightly over four hundred students. There was only one building available for dormitory purposes and this was mostly occupied by younger members of the teaching staff. Most of the students lived down near the foot of the hill or in the nearer parts of down town Ithaca. Ryan's life at Cornell was much like that of other students of those days. Naturally studious and with his interests continuously stimulated by his environment, he gave himself with enthusiasm to his studies.

During this period of student life he evidently made a deep impression on Professor Anthony as a young man of exceptional promise. This resulted in his being selected by Professor Anthony, in his senior year, as his immediate assistant in much of the special work with which he was engaged in those days. The "copper house" and the great tangent galvanometer therein were for many years landmarks at Cornell, recalling Professor Anthony's pioneer work, especially in connection with the establishment of electrical standards. The copper house and the

tangent galvanometer were built during Ryan's student days and he was privileged to work directly with Professor Anthony, not only in the building and installation of this equipment, but also to share with him in some of his pioneer work in which this equipment played a major role.

So passed the years until 1887, when, graduating with a high record, he was offered an instructorship in physics; but, during his later years at Cornell he had made the acquaintance of two students there for graduate work, J. G. White, founder later of the engineering firm of J. G. White and Company of New York City, and Dugald C. Jackson, later distinguished educator and author in the field of electrical engineering. In these years electrical engineering as a profession was the youngest of the great divisions of engineering work. The American Institute of Electrical Engineers was organized in 1884, the year after Ryan's entrance into Cornell. Nevertheless there were then men of vision who foresaw, even though dimly, some part of the great role which it was destined soon to play in carrying forward the developments of the next half century. White, Jackson and Ryan had such faith and such vision; and White and Jackson, planning for the period following the completion of their graduate work, had gotten from Ryan a promise that he would join them in the formation of a company for the active development of projects in the field of electrical engineering in some promising section of the country.

White, having finished his work in 1886, had taken a teaching position in the University of Nebraska at Lincoln and the following year, in 1887, Jackson and Ryan joined him in Lincoln, and White, resigning his position in the State University, these three young pioneers organized themselves into the "Western Electric Company" and carried on actively in Lincoln and the surrounding territory.

This association lasted for about a year; but in the meantime the call of the class room and of life at Cornell had begun to assert itself with growing strength, and, the offer of the instructorship having been repeated, Ryan returned to Cornell in 1888 and took up his work as Instructor in Physics.

In 1885 Dr. Robert Henry Thurston had come to Cornell

from Stevens Institute, as Director of the Sibley College of Mechanic Arts. Dr. Thurston came to Cornell with large plans for widening the scope of Sibley College, for improving its standards and for making of it an engineering school of the highest standing—plans which in gratifying degree were realized, as witness the reputation which this college has enjoyed in later years. Among his first moves for such widening and improvement was the plan of giving distinct recognition to electrical engineering, and of laying down a distinct course in Sibley College, leading to a degree in electrical engineering, and sufficiently divergent in requirements from those for the course in mechanical engineering, to permit of suitable training in electrical theory and correlative laboratory practice.

By the summer of 1888 the time seemed ripe for a definite move toward the realization of these plans.

As noted earlier, the first announcement of special instruction in electrical engineering at Cornell was in the University Register for 1883-84. In that year the trustees gave formal recognition to the earlier work of Professor Anthony and authorized the faculty to "announce a course of study in electrical engineering leading to a degree". The Register, in outlining this course, refers to the "demand for thoroughly trained engineers conversant with electrical science" and to "special studies embracing the construction . . . of dynamo machines and the methods of electrical measurements, electric lighting and the electrical transmission of power." In accordance with these plans, Professor Anthony continued in the direction and development of this work in electrical engineering until 1887 when he left Cornell to undertake electrical development work along industrial lines. At Cornell, Professor Anthony was succeeded in the Department of Physics by Professor E. L. Nichols, and a year later an Assistant Professor of Electrical Engineering was appointed in Sibley College. By understanding between Sibley College and the Department of Physics, it was agreed that the work in electrical engineering would be divided between the two, the former taking over what might be called the more professional aspects of electrical engineering, while the latter would continue to give courses in the scientific background, in

electrical measurements and in dynamo laboratory practice. This general arrangement continued for some years, with a gradual further shift of the work from the Department of Physics to Sibley College. In the meantime, as noted, Ryan, during the year 1888, held his position as Instructor in Physics, but his work, in pursuance of the arrangement noted above, was almost wholly in electrical engineering subjects.

At the beginning of the academic year 1889, the incumbent in Sibley College leaving to take up other work, Ryan was appointed to his place as Assistant Professor of Electrical Engineering in Sibley College and took up his work in the fall of that year in such capacity.

No attempt will be made at this point to appraise in detail his work during the next sixteen years at Cornell. It was characterized by intense activity, notable achievement, and phenomenal growth in the number of students seeking instruction under him. This was due in part to the rapid growth of electrical engineering in those days, but also in no small part, to the faculty which he had of inspiring and stimulating all who came into contact with him in the relation of pupil and teacher.

In the closing months of 1903, Dr. Thurston, Director of Sibley College, died, and in the spring of 1905 there came from Stanford University, California, an offer to head the Department of Electrical Engineering in that institution. The head of his department in Cornell and a full professor in rank, no prospects could have seemed fairer. Beloved by both students and colleagues and with a distinguished record of success both as a teacher and in his personal contributions in the domain of electrical engineering, there was no reason for making a change beyond what may perhaps be termed the call of the West. Stanford University, California and the wide Pacific, all beckoned, and resigning from Cornell he took up his duties in Stanford in the fall of 1905. Here he remained in active service until his retirement as Emeritus Professor in 1931. Following his retirement, with health somewhat impaired, he spent most of his time quietly at his home in Palo Alto, much occupied, among other things, with studies relating to the deaf and the application of electrical aids to hearing for the alleviation of

this all too common handicap to human activity. He had, himself, in his later years suffered from this limitation, and had obligingly submitted himself as a subject to the successive forms of equipment devised in the research laboratories of the American Telephone and Telegraph Company as aids to hearing. Helped as he was by the improving efficiency of these devices he was anxious that others, so far as possible, should share in such benefits and from this desire came the studies which occupied much of his time in these later years.

However, these studies and other matters on which he was thinking were brought to an end in the spring of 1934 by a cerebral hemorrhage which left him with partial paralysis on one side of the body. Following this came a gradual improvement and he was making fair progress toward a comfortable condition of recovery, when on July 3, 1934, a cardiac weakness placed a period to his life.

Such, in bare outline, are the more controlling features of the life of Professor Ryan.

In approaching some account of his professional and scientific achievements, attention is immediately arrested by the third item in the list of his published papers. It is rare, in the scientific work of a man of mark, that so wide a recognition is gained by his third published paper. Speaking of this period of his life, on the occasion of the award of the Edison Medal in 1926, Ryan said:

"In the fourth year of the Institute [A.I.E.E.] I began my work as a faculty man at my alma mater. I found that I was wholly unprepared to assist my students effectively to an understanding of things without end, encountered everywhere; particularly was this so, as matters stood in that day, for the transformer in the alternating-current circuit and the armature reaction effects in the continuous current machine. The alternating-current system for economic incandescent lighting so well suited for the needs of the new rapidly growing American towns and cities had been introduced three years before, i.e., in 1885-6 and its use was being extended rapidly.

With the aid of a friend of my student days, Ernest Merritt, past president of the American Physical Society, I worked through the summer of 1889 upon the problem of systematic measurement upon a particular transformer in sufficient detail

to meet our requirements for teaching. The work was done at Buffalo, New York, through the courtesy of C. R. Huntly, Executive, and H. H. Humphreys, Engineer, of a lighting company of that city. We selected for our specimen a 10-light, 2000 to 50-volt, 133-cycle transformer.

Through Dr. E. L. Nichols, past president of the Institute, I was invited to present a paper based upon our work on the transformer and the results obtained. The paper was duly prepared and presented at the December, 1889, meeting of the Institute in New York City and was published in the Proceedings in January, 1890."

This paper attracted wide attention, both in this country and abroad, and marked the author out as a pioneer in the effective application of the scientific method to the study of the alternate-current transformer, just then beginning to take an established place in the forefront of electrical industry.

In this investigation by Ryan and Merritt, there was obtained, so far as is known, the first complete record of the instantaneous values of the voltage throughout a complete cycle of an alternating current circuit.

In Ryan's work on alternating current phenomena, following soon after his work on the transformer noted above, much use was made, as a tool of research, of the cathode ray indicator or oscillograph, as it has since come to be called. The cathode ray—an indicator without sensible inertia and susceptible to influence by either a magnetic field or an electrostatic field—was, of course, known since the time of Crookes, and had been used in some forms of scientific research. But, so far as is known, it had not been put to use as a tool in connection with the study of alternating current phenomena. Early in his studies on alternating currents, Ryan adopted the cathode ray as a laboratory tool, developing his own form of apparatus and devising an effective means of magnetic control for bringing the beam to a focus. The application of the cathode ray to the study of alternating current phenomena was, after all, more or less an incident in connection with his wider purposes; but it proved a most valuable agency of research, serving for the exhibition of phenomena which could scarcely have been detected otherwise. It has since, of course, become a common-

place in the investigation of complex periodic electrical phenomena, but to Ryan may be credited its first introduction as an agency in the field of electrical engineering with special reference to the phenomena of alternating currents.

Another outstanding result of Ryan's investigations was given to the public in his paper with M. E. Thompson, "A Method for Preventing Armature Reaction," in the Transactions of the American Institute of Electrical Engineers under date of March 20, 1895. This paper dealt with the results of studies begun in 1892 with his students, on commutation in direct current machines and characteristic behavior in relation to the shape of poles, length of airgap and related factors. The first practical application of the results of these studies was in the Thomson-Ryan generator with pole-face winding, which was the forerunner of the present day interpole type of construction now almost universally used in direct current motors and generators.

But Ryan's chief work, especially in his later years, was focused on problems arising in connection with the long distance transmission of power. In the early nineties of the last century, there were wide differences of opinion regarding the possibilities of transmitting power over long distances and likewise whether direct or alternating current offered the greater promise.

Ryan's first approach to the laboratory study of high voltage phenomena was in 1893 when he constructed at Cornell an oil immersed 30,000 volt transformer. This, on trial, promptly burned out and was replaced by one with air insulation. This was again rebuilt in 1899 for 90,000 volts and continued to give good service for many years thereafter.

It was about this time, in 1897, based on the results of tests made on certain power lines operating in the Rocky Mountains, that serious doubt was cast on the possibility of exceeding 40,000 volts for the long distance transmission of power. These tests indicated that, dependent on a number of obscure factors, electric energy at this voltage would escape rather freely into the atmosphere, thus affecting seriously the efficiency of transmission. The whole future of the long distance transmission of power seemed at stake.

Ryan felt that the conclusions based on these results were too hasty and that the matter called for more extended study. He accordingly undertook a series of investigations continuing until 1904 when he presented a paper entitled "The Conductivity of the Atmosphere at High Voltages". The fundamentals set forth in this paper were a distinct contribution to electrical science. The law of corona formation was established, and the conditions under which corona leakage could be controlled were set forth. The limitation of 40,000 volts was shown to be non-existent, and the way was cleared for the advances in more recent years to a present maximum * of about seven times that earlier apparent limit.

Ryan's studies on insulation and insulators for use on high voltage lines also formed a notable contribution to this phase of power transmission. These were carried on especially over the period 1915-25. These investigations covered the distribution of voltage across the different units making up strings of insulators and the best manner of equalizing the same; the cause and effect of the ageing of porcelain, the causes of failures and flashovers, and allied problems. These studies have been an important factor in those improvements of insulators, both in design and in product, which have made possible the operation of great modern transmission systems with voltages of 220,000 and 275,000.

In connection with his various studies of the problems of high voltage and long distance transmission, Ryan developed a number of new and improved methods of observation and measurement. The adaptation of the cathode ray to the study of periodic phenomena has been mentioned. Another notable example was the high voltage wattmeter. This was a device planned for the more accurate measurement of line losses in high tension power transmission than had been hitherto available. With measurements made on an energized open-circuit line, the results should give, of course, the line losses, or, specifically, the so-called corona loss. And by making such measurements under a series of operating conditions (especially as regards size and character

* The Boulder Dam Power Line Transmission to Los Angeles.

of cable and operating voltage) a relation could be developed between the loss per thousand feet, or per mile of line, and such operating conditions.

The device comprised the necessary current and potential coils, as found in the usual type of low tension wattmeter, the former supplied by a few turns of the main circuit, the latter by a suitable coil and circuit, carrying in series with the coil a special form of water resister. In addition, special shielding arrangements were used in such way that the losses in the leads up to the main line were supplied directly from the transformer and thus eliminated from the indications of the instrument.

By means of this type of wattmeter it became possible to measure with satisfactory accuracy the losses involved in high tension power transmission, and long series of such measurements were made, and related to voltage, type, form and size of conductor, atmospheric conditions, etc., and a vast amount of information obtained of the greatest value in the design of modern high tension transmission lines and their equipment.

In connection with his various studies—on pole face winding, cathode ray magnetic focusing, etc., Ryan took out a number of patents, but he was never one to follow these to his own personal advantage and their benefits went, for the most part, to the industry at large.

In recognition of Ryan's outstanding work in the field of high voltage long distance transmission and as an evidence of the desire for its assured continuance, the leading public service companies of California together with manufacturers of electrical equipment, in 1923-24, provided funds for the establishment of a modern up-to-date high-tension laboratory at Stanford University where fundamental research in connection with these problems could be carried on in advance of the industry. This laboratory, with equipment complete and in working order, was opened in 1926, with demonstration of its capacity for producing and handling electricity under tensions up to 2,000,000 volts. In compliment to the man whose work was recognized by this splendid memorial, the laboratory has been given his name and is known as the Harris J. Ryan High Tension Laboratory.

Ryan continued actively in this laboratory his researches on various phases of long distance power transmission until his retirement from active status in 1931 with passage to the Emeritus role. In further honor, however, he was named Honorary Director of the Laboratory and so continued until his death in 1934.

While Ryan's chief work has lain in the domain of the long distance electrical transmission of power, he made many interesting and effective contacts in other directions. Thus in the domain of radio transmission, it was a student of Ryan's, Mr. C. F. Elwell, who brought the Poulson Arc patents to the United States and in frequent helpful conference with his professor, made the initial experiments which laid the foundation for the Poulson arc radio system as later developed in this country and abroad.

In 1893 Ryan served as a member of the Jury of Awards in the Department of Electricity at the Chicago International Exposition, and again in the same capacity in 1915 at the Panama Pacific Exposition in San Francisco. In 1904 he was a delegate to the International Engineering Congress at St. Louis held in connection with the Louisiana Purchase Exposition of that year.

Again, during the war period, Ryan headed a group of researchers at the California Institute of Technology in Pasadena, dealing with the problem of supersonics as applied to the detection of the submarine. This work was carried on under the National Research Council as the agency for the mobilization of the scientific effort of the United States on war problems. The special problem with which this group was concerned was the investigation of ways and means for the increase of energy per unit area of radiating crystal surface, as compared with the values previously obtained. Good progress was being made on the elements of this problem when the Armistice brought the effort to a close.

From 1909 to about 1923 Ryan served as a member of a board of consulting engineers to the Los Angeles Municipal Bureau of Power and Light, especially with reference to the pioneer work of this Bureau in connection with the design of the hydro-

electric generating stations in San Francisquito canyon along the line of the Los Angeles Owen's River Aqueduct. Still later, in 1932-34, important studies relating to the transmission line for power between Boulder Dam and Los Angeles were carried on in the Ryan High Tension Laboratory to which he contributed through frequent consultations regarding the principles involved and the strategy to be employed. As a result, largely of these studies, the practicability of a transmission voltage of 275,000 was clearly indicated for the controlling conditions presented, including in particular, the length of transmission line and the amount of power per circuit. This voltage was adopted for the line, a definite step in advance beyond the then maximum of 220,000, a choice which has been fully justified by the successful operation of this line since the autumn of 1936.

Many opportunities came to Professor Ryan in the way of private consulting practice, but for the most part, they were declined due to physical health and strength none too rugged, and to his absorption in his work of research. He felt that he could not do justice to both and he considered the latter as by far the more important. With the organization and equipment of the High Tension Laboratory, however, and through cooperative arrangements, it became possible to carry on investigations of great fundamental importance, not only to the organization in which the special problem may have arisen, but to the entire profession at large, as witness the investigations relating to the Boulder Dam transmission line and others of similar character.

While Ryan's contributions in the domain of electrical engineering have been of outstanding importance and value, his chief contribution to his day and age is to be found, after all, in the lives and works of the men whom he influenced through the relationship of teacher and student. He viewed his function as a teacher with the utmost seriousness. He was fond of referring to himself as a "Faculty Man" and he considered his work always from the standpoint of helpfulness to his students. For more than forty years one class followed another; in the aggregate a goodly company, taking with them to all parts of the world something gained from their contacts with this man whose first thought always was for the good of his students.

Through this human product the successful teacher achieves an immortality; he lives on in the lives of those whom he has influenced and helped.

Growing out of conditions in what may be termed the new era of Japan, it was but natural that, during the period 1900-30, there should have been a large influx of Japanese students to the United States, seeking instruction in subjects relating to engineering and technology. Especially was this true in electrical engineering, the youngest of the great divisions of engineering activity. Naturally a goodly share of such students gravitated to Stanford University with its convenient location on the Pacific Coast and with opportunities for instruction under Ryan as the immediate goal. Most of these, after graduation, returned to Japan, taking positions either in the industry or in teaching, thus forming a considerable segment of the field of electrical engineering in Japan tracing its training back to Stanford and Ryan, with a few tracing still earlier to Cornell and Ryan.

In addition to students from Japan and from other foreign countries, a number, in the years following the Great War, came to Stanford University on "Commonwealth Fund" and "C.B.R." (Commission for Belgian Relief) fellowships, in order to follow the work in electrical engineering under Professor Ryan.

As evidence of the high regard with which Ryan was held in Japan and especially by his former students both at Stanford and Cornell, he was the first scientist from the United States to be invited to give a course of lectures in Japan on the Iwadare Foundation of the Institute of Electrical Engineers of Japan. This was in 1933. The invitation was accepted, but ill health compelled a cancellation or perhaps rather a postponement of the plans. Later, improving health gave promise that he might be able to make the long anticipated trip to Japan and carry out the program of lectures; but the return to adequate health and strength was denied, and Professor Ryan passed on without having seen his "Carcasonne".

The deep affection felt for Ryan by his former students and the fine sense of personal friendship which they cherished for him, were further shown by an impressive memorial service

held in Tokyo, Japan, on the evening of October 3, following his death.

The gathering was sponsored by Dr. Shibusawa of the Imperial University and attended by twenty electrical engineers and educators in Japanese universities who had studied at Stanford or Cornell and under Ryan.

In a letter to Mrs. Ryan from Mr. S. Motomura, the following paragraph descriptive of this occasion may be quoted:

"After dinner together, the group adjourned to a separate room where a photograph of the late Dr. Ryan was placed in front of a wreath donated by the Stanford Alumni Association of Japan. Reminiscences of their days at Stanford were given by many, in which the greatness of Dr. Ryan as both scientist and man was brought out. That the electrical industry in Japan, especially in fields of high voltage, owes a tremendous debt to him was emphasized. A memorial photograph of the group was taken, and after all had silently bowed before the photographic likeness of Dr. Ryan, as a last tribute, the meeting adjourned."

Further evidences of the love and esteem in which Ryan was regarded by his colleagues and former students were shown by a notable dinner given him on the occasion of his retirement from active service in 1931; and following his death in 1934 by resolutions of the Academic Council of Stanford University, of the Governing Body of the American Institute of Electrical Engineers, and by the many letters, telegrams and messages of condolence received by his widow.

The American Institute of Electrical Engineers was organized in 1884. Ryan, as a young graduate of Cornell University, joined in 1887, was advanced to the grade of Member in 1895 and in 1923, on the organization in that Society of the grade of Fellow, he was immediately, with others in a selected group, advanced to that grade. He served the Society on numerous committees, was elected Manager for the period 1893-96, served as Vice-President 1896-98 and as President, 1923-24.

In 1925 he was awarded the Edison Medal of the Society under the citation:

"For his contributions to the science and the art of high-tension transmission of power".

The ceremonies of award were held on the occasion of the Pacific Coast Convention of the Institute in Salt Lake City on September 8, 1926. Ryan's life work was reviewed by Mr. Paul M. Downing, Vice President of the Society, and the award was made by President C. C. Chesney. In his reply, Ryan made references to some of his earlier work in terms from which quotations have been given at earlier points.

Besides the American Institute of Electrical Engineers, Ryan was a Fellow of the American Association for the Advancement of Science, and held membership in the American Society of Mechanical Engineers, the American Electro Chemical Society, the Institute of Radio Engineers, the American Physical Society and the Society for the Promotion of Engineering Education. He was also a member of Sigma Xi and of Tau Beta Pi. In 1920 he was elected to the National Academy of Sciences. In matters of technical society activity, however, his chief loyalty was always with the American Institute of Electrical Engineers, and practically all of his papers dealing with original investigations were given to the public through the Transactions of that body.

On graduating from Cornell, Ryan received the degree of M.E., (E.E.), one of the earliest to receive a distinctive degree in electrical engineering from an institution of higher learning. In 1925 he was awarded the honorary degree of LL.D. by the University of California.

In approaching any general integration of Professor Ryan's outlook on life or his attitude toward his professional work, note must first be taken of his friendliness with all with whom he came in contact, and of his capacity for making and holding friends. This was evidenced not only by the continuing warm friendly relations maintained with those who had come to know him as a teacher, but by all with whom he came in contact in the various relations of life. There was always a pleasant greeting, a kindly word and a friendly interest in the problems and troubles of others.

In his scientific and technical work, he was always thinking of the future. His problems and his chief interests were centered on the long look ahead. His was distinctly the spirit of

the pioneer as witness his early work on pole face windings and on the transformer, on the electrical properties of the atmosphere with reference to the high tension transmission of power, his studies on insulation and insulator chains and other like problems. Much of the development of the applied art in electrical engineering followed upon and was conditioned by the results of these studies.

On September 12, 1888, the young Instructor Ryan married Katherine E. Fortenbaugh, a girl of his home town, Halifax, Pa. Mrs. Ryan joined most heartily with her husband in making their home a place of cheerful welcome for students, and the Ryan house was always a shifting scene of friendly calls from students past and present, with always a warm greeting and kindly interest in their welfare. Mrs. Ryan must share with Professor Ryan in the making of this atmosphere of friendly welcome which was always so characteristic of the Ryan home.

BIBLIOGRAPHY

Ryan's contributions to engineering and technical literature were numerous and important. The list of principal titles follows:

The spiral coil voltometer. Proc. Amer. Inst. Electr. Eng., vol. vi, Aug.-Sept., 1889, p. 322.

A quadrant electrometer. Proc. Amer. Assoc. Adv. Sci., 38th meeting. 1889, p. 132.

Transformers. Proc. Amer. Inst. Electr. Eng., vol. vii, Jan., 1890, p. 1.

Some experiments upon alternate current apparatus. Proc. Amer. Inst. Electr. Eng., vol. vii, 1890, p. 324.

On the relation of the air gap and the shape of the poles to the performance of dynamo machinery. Trans. Amer. Inst. Electr. Eng., vol. vii, Oct., 1891, p. 451.

Notes on electrical engineering. Ithaca, 1892. Unpaged. Illus.

Heating of armatures. Electr. World, vol. xx, Oct. 22, 1892, p. 260.

On a method for balancing armature reactions. Sibley Journ., vol. vii, Oct. 1892, p. 547.

The reversal of polarity in plating dynamos. Trans. Amer. Inst. Electr. Eng., vol. ix, 1892, p. 524.

Test of a Stanley 27,500 watt transformer. Electr. Eng., vol. xiv, Sept. 23, 1892, p. 298.

Review of, A dictionary of electrical words, terms, and phrases, by E. J. Houston. Electr. World, vol. xix, June 11, 1892, p. 394.

The efficiency of alternating plants. Electr. Eng., vol. xv, Jan. 4, 1893, p. 12.

Dynamo electric machinery. Johnson's Universal Cyclopedia, vol. ii, Electric motor. Electric railways, vol. iii.

A cable rupture. Sibley Journ. Eng., vol. vii, April, 1893, p. 283.

Kapp's alternate current problems. Sibley Journ. Eng., vol. viii, Feb., 1894, p. 199; Electr. Eng., vol. iii, April, 1894, p. 176.

Associate editor. Sibley Journ. Eng., April, 1893-March, 1894.

The behavior of single phase motors. Sibley Journ. Eng., vol. viii, No. 8, May, 1894.

Alternate current working. Electr. World, vol. xxiii, Jan. 6-June 30, 1894, pp. 8, 80, 268, 315, 462; vol. xxiv, July 7-Dec. 29, 1894, pp. 382, 461.

A method for measuring telephonic currents and electromotive forces. Electr. World, vol. xxiii, 1894, p. 833.

Sine form of curves of alternating electromotive forces. Electr. World, vol. xxiv, 1894, p. 177.

What shall be the measure of phase difference? Electr. World, vol. xxix, 1894, p. 475.

The university light and power station. (With I. J. Macomber.) Sibley Journ. Eng., vol. viii, Dec., 1894, p. 91.

A method for preventing armature reaction. (With M. E. Thompson.) Trans. Amer. Inst. Electr. Eng., vol. vii, March 20, 1895, p. 84.

Definition of polyphase systems. Electr. World, vol. xxv, March 30, 1895, p. 399.

Action of a single phase synchronous motor. (With F. Bedell.) Journ. Franklin Inst., March, 1895; Electr. World, vol. xxv, March 30, 1895, p. 391.

Improvements in armature ventilation. Sibley Journ. Eng., April, 1895.

The behavior of the carbon brush on the commutators of direct current power generators. Sibley Journ. Eng., vol. x, Oct., 1895, p. 22.

Load losses produced by armature currents. Electr. World, vol. xxviii, July 4-Dec. 26, 1896, p. 272.

Induction motor design. (With I. J. Macomber.) Sibley Journ. Eng., vol. xii, Nov., 1897, pt. I, p. 39; pt. II, p. 81.

The design of a one hundred kilowatt five hundred volt power generator. (With I. J. Macomber.) Sibley Journ. Eng., vol. xi, Jan., 1897, p. 125.

The determination of the wave form of alternating currents without a contact maker. Trans. Amer. Inst. Electr. Eng., vol. xvi, June 26, 1899, p. 345.

Some electric railway data. Proc. Street Railway Association of the State of New York, Sept. 12-13, 1899.

Text-book of electrical machinery. (With H. H. Hutchinson and G. L. Hoxie.) John Wiley and Sons, 1903.

The Cathode ray alternating current wave indicator. Trans. Amer. Inst. Electr. Eng., vol. xxii, 1903, p. 539.

Contribution to discussion of alternator design. Trans. Amer. Inst. Electr. Eng., vol. xxii, 1903, p. 539.

Institute branch meetings. Trans. Amer. Inst. Electr. Eng., vol. xxii, 1903, pp. 67, 69.

A text-book of electrical machinery. (With Henry H. Norris and George L. Hoxie.) Electr. Machinery, vol. i, 1903, John Wiley and Sons, New York.

The conductivity of the atmosphere at high voltages. Trans. Amer. Inst. Electr. Eng., vol. xxiii, 1904, p. 101.

Some elements in the design of high pressure insulation. International Electrical Congress, St. Louis, vol. i, 1904, p. 575.

Compressed gas as an insulator. Electr. Journ., vol. ii, 1905, p. 429; Electr. World and Eng., vol. xlvi, July 22, 1925, p. 148.

Contribution to the discussion of Corona phenomena in air and oil and their relation to transformer design. Trans. Amer. Inst. Electr. Eng., vol. xxviii, pt. 2, 1909, p. 802.

Preliminary report of consulting board of engineers of the Bureau of Los Angeles aqueduct power. (With O. H. Ensign and W. F. Durand.) Los Angeles, February 12, 1910.

Contribution to discussion of protecting insulators. Trans. Amer. Inst. Electr. Eng., vol. xxix, 1910, p. 610.

Contribution to discussion of parallel operation of three-phase generators with neutrals interconnected. Trans. Amer. Inst. Electr. Eng., vol. xxix, 1910, p. 791.

Contributions to discussion of observations of harmonics in voltage wave shapes of transformers. Trans. Amer. Inst. Electr. Eng., vol. xxix, 1910, p. 891.

Contribution to discussion of electric strength. Trans. Amer. Inst. Electr. Eng., vol. xxix, June, 1910, p. 1217.

Open atmosphere and dry transformer oil as high voltage insulators. Trans. Amer. Inst. Electr. Eng., vol. xxx, Feb., 1911, p. 1.

A power diagram indicator for high-tension circuits. Trans. Amer. Inst. Electr. Eng., vol. xxx, April, 1911, pt. ii, p. 1089.

Polarity in polyphase current circuits. Journ. Electr. Power and Gas, vol. xxvii, Nov., 1911, p. 447.

Contribution to discussion of electric strength of air. Trans. Amer. Inst. Electr. Eng., vol. xxx, June, 1911, pt. iii, p. 1976.

Contribution to the discussion of electrical characteristics of the suspension insulator. Trans. Amer. Inst. Electr. Eng., vol. xxxi, May, 1912, p. 944.

Contribution to the discussion of insulation. Trans. Amer. Inst. Electr. Eng., vol. xxxii, March, 1913, pt. i, p. 946.

Contribution to the discussion of corona. Trans. Amer. Inst. Electr. Eng., vol. xxxii, June, 1913, pt. ii, p. 1825.

High voltage laboratory. Stanford Alumnus, Dec., 1913.

Contribution to discussion of theory of the corona. Trans. Amer. Inst. Electr. Eng., vol. xxxiii, April, 1914, pt. i, p. 607.

Sphere gap discharge voltages at high frequencies. (With J. Cameron Clark.) Trans. Amer. Inst. Electr. Eng., vol. xxxiii, June, 1914, pt. i, p. 973.

Contribution to the discussion of the Cathode ray tube as a power factor indicator. Proc. Amer. Inst. Electr. Eng., vol. xxxv, 1915, p. 29.

Sporadic insulator troubles. Journ. Electr. Power and Gas, vol. xxxiv, Feb. 27, 1915, p. 162.

High voltage potentiometer. Journ. Electr. Power and Gas, vol. xxxiv, April 10, 1915, p. 290.

Contributions to the discussion of electrical porcelain. Proc. Amer. Inst. Electr. Eng., vol. xxxiv, Feb., 1915, p. 2641.

Address closing technical sessions of Electrical Engineers section of the Panama-Pacific International Engineering Congress, San Francisco, Sept. 25, 1915. Proc. Amer. Inst. Electr. Eng., vol. xxxiv, p. 251 (Introductory Section).

Contribution to the discussion of phenomena accompanying transmission with some types of star transformer connections. Proc. Amer. Inst. Electr. Eng., vol. xxxv, Sept., 1915, p. 431.

Sustained radio frequency high voltage discharges. (With Rowland G. Marx.) Proc. Inst. Radio Eng., vol. iii, Dec., 1915, p. 349.

Contribution to the discussion of the electric strength of air. Proc. Amer. Inst. Electr. Eng., vol. xxxiv, 1915, pp. 3002, 3003, 3004.

The high voltage potentiometer. Proc. Amer. Inst. Electr. Eng., vol. xxv, Aug., 1916, p. 1187.

Porous porcelain for high voltage insulators. Journ. Electr. Power and Gas, vol. xxxvii, Sept. 23, 1916, p. 243.

Ceramics in relation to the durability of porcelain insulators. Paper read at the meeting of the San Francisco section of the American Institute of Electrical Engineers, Nov. 24, 1916; Trans. Amer. Inst. Electr. Eng., vol. xxxv, 1916, p. 1437.

Discussion on: Peaslee: The insulator situation; Brundige: Expansion effects as a cause of deterioration in suspension type insulators; and Austin: Present practice in the design and manufacture of high tension insulators. Presented at a special meeting of the American Institute of Electrical Engineers, New York, June 27, 1917. Trans., vol. xxxvi, 1917, pp. 101-133.

The work of the electrical engineer, an assembly address at Throop College, May 26, 1919. Reprint from the Throop College Bulletin, vol. xxviii, No. 64, July, 1919.

Researches in high voltage insulation. Electr. World, vol. lxxv, January 31, 1920, pp. 254-56.

Suspension insulator research. National Electric Light Association. Overhead sections committee report. Advance copy prepared for presentation at 43d convention. Pasadena. May 18, 22, 1920. Review in Electr. World, vol. lxxv.

Unit voltage duties in long suspension insulators. (With H. H. Henline.) Amer. Inst. Electr. Eng. Journ., vol. xxxix, July, 1920, pp. 631-6.

High voltage research experiments. Journ. Electr. and Western Industry, vol. xlv, Dec. 15, 1920, p. 560.

Suspension insulator research. (With Raymond Lewelling.) Report of the overhead systems committee technical section of the National Electric Light Association. Advance copy prepared for the 44th convention. Chicago, 1921, pp. 83-85.

Insulator progress during 1920. Electr. World, vol. lxxvii, Jan. 1, 1921, p. 30.

Research cooperation between universities and utilities. Electr. World, vol. lxxix, Jan. 7, 1922, p. 8.

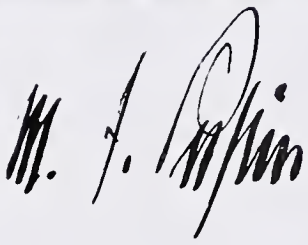
Introductory remarks as presiding officer. Fortieth anniversary celebration of the American Institute of Electrical Engineers. Amer. Inst. Electr. Eng. Trans., vol. xliii, Feb. 1924, pp. 104, 109, 113.

The hysteresis character of corona formation. (With H. H. Henline.) Amer. Inst. Electr. Eng. Trans., vol. xliii, Feb. 1924, pp. 118-24.

A generation of the American Institute of Electrical Engineers, 1884-1924. President's address. Amer. Inst. Electr. Eng. Trans., vol. xliii, June, 1924, pp. 740-4.

Discussion. Wilkins' corona loss test. Amer. Inst. Electr. Eng. Trans., vol. xliii, 1924, pp. 1169-71.

Transmission problems of the future. Elec. World, vol. xxcv, June 6, 1925, pp. 1205-06. Portrait.



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OF

MICHAEL IDVORSKY PUPIN

1858–1935

BY

BERGEN DAVIS

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MICHAEL IDVORSKY PUPIN

1858–1935

BY BERGEN DAVIS

The subject of this memoir was born on October 4, 1858, in the small village of Idvor in the Banat of Austria—an Austrian citizen, he was pure Serbian in race. His father, Constantine, and his mother, Olympiada, were sturdy peasants in moderate circumstances. The parents illustrate the very significant difference between intelligence and education. Neither of them could read or write. His father, however, was several times elected "knez" or chief of his village. His mother was a woman of great piety, wisdom and mental vigor. All readers of "From Immigrant to Inventor" will be impressed by the great influence she exerted on the character, early education, and future career of her son Michael.

In 1690, upon the invitation of King Leopold I of Austria, thirty-five thousand picked Serbian families moved from Serbia to the north side of the Danube River into a province known as the Banat. These Serbs were invited there to guard the Austrian frontier against the Turks. A narrow strip of territory was assigned to them. Idvor was one of these settlements. Although technically citizens of Austria, these settlers retained the language and folk-ways of old Serbia.

From this ancestry and from the struggle with the physical characteristics of the land, Pupin acquired great powers of self-discipline, and also derived his poetical temperament, his imagination and his courageous spirit.

His formal education was begun in the village school of Idvor, where he learned reading, writing and arithmetic. As he showed marked mental vigor and capacity, his mother prevailed upon his father to send him to school first in Pechavo, and later to Prague. An incident that occurred on his journey to Prague had an influence on his later emigration to America. He journeyed down the Danube to Budapest, where he took a train bound for Vienna. He was to have changed at Gaenserndorf for Prague. The compartment was warm. He fell asleep and was

carried directly into Vienna. Having no money to pay his return fare, he was hailed before the station master, in the boy's eyes, an awesome official in uniform. He was brow-beaten and insulted by this petty official. An elderly couple who witnessed the affair came forward and offered to pay the young man's fare to Prague, to which place they themselves were bound. They took him with them into a first-class coach. On this journey, he learned that his new-found friends were from America, the country of Benjamin Franklin of whom he had read. During this ride from Vienna to Prague, these generous Americans treated him as an equal and, on arrival in Prague, took him to their hotel as a guest until he could get established in lodgings.

After about a year in Prague, his father died, and, fearing his schooling would be too great a burden on his mother, he decided to emigrate to America. To get the necessary money for his passage to New York in the steerage, he sold his books, his watch, and his great sheepskin coat. He sailed for New York on March 12, 1874, on the steamship "Westphalia." He suffered greatly from cold on this trip (minus his great coat). His experiences form an interesting paragraph in his autobiography. After a painful voyage of fourteen days, he landed in New York on March 26th with five cents in his pocket and a red fez on his head.

His first job was that of driving a team of mules on a farm in Delaware. He also began to learn English under the tutelage of the daughter of the farmer. He also learned much of American thought and customs, which were new and strange to him. After a few months on this farm, he drifted back to New York City and spent the winter of 1874-75 in great hardship. He walked the streets seeking work, performing odd jobs of painting and unloading coal into basements. The evenings were spent in reading in the library of Cooper Union. In the spring of 1875 he again went to work on a farm near Dayton, New Jersey. The persistent efforts of the farmer and family to convert him to their narrow religious views became intolerable. He returned to New York and finally found work in a cracker factory on Cortlandt Street. His experiences there and the accounts of his friends Jim and Bilharz form one of the most

interesting chapters in "From Immigrant to Inventor." The early chapters of this book are of great interest and should be read by all who are interested in the problem of Americanization of immigrants. During the next three years, he attended evening classes at Cooper Union and strenuously trained himself in English by conversation, discussion with Bilharz and Jim, and by attendance at the theater. In the meantime, by industry and thrift he accumulated a modest sum in a savings bank. His friend Bilharz at the cracker factory, who was a classical scholar, helped him to prepare for college.

His career at Columbia College, which he entered in the autumn of 1879, was a successful one, not only academically, but also in a social way. He took a prominent part in athletics, won a number of prizes in Greek and mathematics, and was elected president of his class in his senior year. While in college, he became much interested in the classics, particularly Greek, but his enthusiasm for physical science was aroused by witnessing Faraday's experiment on electro-magnetic induction as performed by Professor Rood in the classroom. He resolved to find out all about this wonderful phenomenon. On graduation in 1883, he was appointed first Tyndall Fellow in Physics from Columbia College. The next six years were spent at the Universities of Cambridge, England, and Berlin.

At Cambridge he was occupied principally with mathematical physics and became especially interested in the electro-magnetic theory of Maxwell. After a year or so at Cambridge, he went to Berlin and, at the suggestion of Helmholtz, began a research in the new science of physical chemistry. He completed a dissertation on the subject of "Osmotic Pressure and Free Energy," receiving the degree of Doctor of Philosophy in 1889.

Before returning to America, Professor Pupin married Sarah Katherine Jackson, the widow of Frederick J. Agate, and the sister of his classmate and future colleague, Professor A. V. Williams Jackson.

Pupin returned to Columbia as instructor in the newly created department of electrical engineering, he and his friend, Francis B. Crocker, constituting the whole staff of that department. Later he was made Adjunct Professor, and in 1901 was ap-

pointed Professor of Electro-Mechanics. The basic theoretical courses in electrical engineering were given by Pupin in the mornings, and in the afternoons he was required to give laboratory instruction. Notwithstanding a heavy teaching load, he found time in the evenings to carry on with experimental research. His earliest work was in the field of electrical phenomena associated with the discharge of electricity through gases.

As a result of his teaching duties, he became interested in electrical engineering problems and occupied himself with the experimental investigation of the peculiarities of wave forms of alternating currents, to which Professor Rowland of Johns Hopkins University had called his attention. His familiarity with the methods of Helmholtz in analyzing complex sound wave forms by means of resonators enabled him to apply a similar method to the analysis of complex current wave forms. This he accomplished by the use in electrical circuits of adjustable condensers and inductances. He was thus led to the discovery of electrical tuning, which is so essential in the art of radio communication.

In December, 1895, Roentgen announced his epoch-making discovery of X-rays. Pupin became interested immediately, and two weeks later, on January 2, 1896, he took the first X-ray photograph made in America. With the aid of a phosphorescent screen, furnished by his friend Thomas A. Edison, superimposed on a photographic plate, he was able to make good X-ray pictures in a few seconds of exposure. In a communication to the New York Academy of Sciences on April 6, 1896, he announced the discovery of secondary X-radiation and is now generally accorded priority for that discovery.

On April 15, 1896, Professor Pupin was stricken suddenly with pneumonia. After a few days of anxious care of him, Mrs. Pupin was also seized with the same disease and died after a short illness. This illness and loss were a great shock, and were followed by great depression of spirit. Upon the advice of his physician, he spent the following summer at Norfolk, a village in the Berkshires, in the northwest corner of Connecticut. Convalescence was slow until his physician, a lover of horses, presented him with a pair of beautiful young cobs only partially

trained from his stud. Boyhood love of horses and his interest in training them brought back health by the end of the summer. Comet and Princess Rose, under his skillful training, became prize winners at the New York and Philadelphia horse shows of 1897-98.

Naturally, he became much attached to Norfolk and the following year purchased a farm near the village. About ten years later, using stones from the fields, he built his picturesque summer home, to which he was accustomed to go not only for rest, but also for opportunity to work, free from the distractions of city life. This home is now the residence of his daughter, Mrs. L. Graham Smith, and her husband.

Upon recovery from his illness, Pupin returned to a problem which eventually led to the invention of the "loaded line." While in Paris, fifteen years previously, he had found at a riverside bookstall a treatise by La Grange containing a paper, "Researches sur la Nature et la Propagation du Son," in which a solution was given of the problem of a vibrating string fixed at each end and loaded at equal intervals with equal masses. Pupin now proposed to generalize the conditions assumed by La Grange, through assuming the string itself to have mass, and the medium surrounding the string to exert a dissipative reaction to its motion. He was able to obtain a solution of this more general problem, but did not at the time realize its tremendous practical importance.

This investigation furnished a solution of the exactly analogous problem of the propagation of electro-magnetic signals over telephone lines having distributed capacity and loaded at equal intervals with inductances. Professor Pupin's investigation showed that the malevolent influences of capacity and resistance in causing distortion and attenuation could be overcome by the introduction of inductances at specified distances along the line.

This invention of the "loaded line" was of the highest importance in telephone transmission. Before this invention, long distance telephoning was impossible. Also, before the year 1900, the streets of large cities such as New York were disfigured by telephone poles carrying hundreds of wires. It was not prac-

tical to transmit, even for short distance, over wires placed underground. The loaded line made transmission possible on underground cables over much longer distances. The unsightly overhead wires completely disappeared from our city streets.

The American rights to this invention were acquired by the American Telephone and Telegraph Company. This "loading" is used universally in the art of telephone transmission throughout the world. The German rights were acquired by the Siemens and Halske Company. This loading of telephone lines is called "pupinization" on the continent of Europe.

The use of loading coils had an enormous growth in the first quarter-century after this invention. By 1911 there were 125,000 loading coils in use on 85,000 miles of open circuit and 170,000 miles of cable circuits. By 1926 there were 1,250,000 coils in use on 1,600,000 miles of cable and 250,000 miles of open wire circuits. The writer is informed by an engineer of the American Telephone and Telegraph Company that at the end of 1936 there were over 8,500,000 loading coils in service in the United States. There are approximately 5,000,000 circuit miles of loaded toll cable and 4,000,000 circuit miles of loaded local cable in use.

A prominent electrical engineer has estimated that in the first twenty-five years this invention saved the American people more than one hundred million dollars.

Not long after the sale of his telephone invention, Pupin disposed also of his wireless inventions, such as electrical tuning and the electrolytic rectifier, to the Marconi Company of America. For many years after the first announcement of the principle of "loading," he was immersed in the many problems that arose in connection with the practical application of loading coils to telephone circuits. These practical problems absorbed much of his attention up to the outbreak of the World War. These problems and this latter event diverted Pupin's attention and prevented his participation in the advancement of pure physics in which he began his career and in which he always remained so much interested.

After the solution of the many problems that arose in connection with the introduction of the "loaded line" into prac-

tice, Pupin carried forward many interesting experiments in alternating current phenomena. As early as 1899 he developed and published a theory of artificial lines called "net works." This theory contained the mathematical foundations used in the construction of electrical filters at the present time. The negative resistance idea was suggested by Pupin and was first produced by running an induction motor beyond synchronism. He showed that if such a negative resistance is introduced in a circuit containing inductance, capacity and resistance, continuous electrical oscillations can be produced. A student, E. H. Armstrong, working in his laboratory, produced this negative resistance by means of the three electrode vacuum tube. This led him (Armstrong) to the invention of the high frequency vacuum tube oscillator, which is the foundation of modern radio broadcasting.

In his later years Pupin withdrew largely from personal scientific research. His time and thought, especially after the World War, were given to semi-public affairs. He made many public addresses before scientific and educational institutions. The underlying theme of many of these addresses was idealism in science and American idealism in life. He was an eloquent speaker, possessed a forceful personality and was endowed with a poetic imagination that gave great pleasure and profit to popular audiences.

One result of this popular activity was the writing and publishing of that remarkable book, "From Immigrant to Inventor." In this he tells of his boyhood life in Idvor, of his journey to America at the age of sixteen, of his hardships and fortitude in these, his struggling years. A book remarkable for its merit as literature, it is filled with the charm of a poetic imagination. Here, too, a major theme is idealism in American science. This book had a great popular appeal and has had a large and continuous sale up to the present time. It has been translated into several foreign languages, and letters of appreciation from all over the world gave the author assurance that his time and labor had not been in vain. On account of persistent demand, an abridged edition was issued suitable for use in the public schools.

In 1927 he issued another book based on the ideas he had put forth in his popular addresses. The title was "The New Reformation." The purpose of this book may be inferred from the concluding words of the prologue: "It is hoped by strengthening our understanding of the physical realities, these narratives will reform our mental attitude and make it better prepared for the recognition of the truth that physical and spiritual realities are the fruit of the same tree of knowledge, which was nurtured by the soil of human experience." In this book, writes his colleague and friend, Professor A. P. Wills, "Pupin has revealed the simple and rational philosophy of life to which he adhered and the spiritual sentiments which were a part of his religious faith."

At the outbreak of the Balkan War in 1912, Pupin was appointed Honorary Consul General and, I believe, was the only diplomatic representative of Serbia in America during the Balkan and the World Wars. He started at this time, at his own expense, a Serbian daily newspaper, mainly for the purpose of keeping Serbian immigrants informed as to the war movements in the Balkans. He also organized a Serbian sisterhood whose members were encouraged to collect contributions to the Serbian Red Cross, and, in the interest of the Serbian National Defense League, to inspire volunteers for the service. In 1914 this work was extended throughout the United States, and highly satisfactory results were obtained.

As the only representative of Serbia in America during the World War, he had charge of that government's purchases, and in at least one instance personally assumed large financial responsibility for the same. He headed the committee formed in this country to help Serbian war sufferers. He was active in the formation of the Serbian Child Welfare Association which did noble work in providing medical supplies, clothing and homes for Serbian war orphans.

At the conclusion of the World War, Premier Paskitch invited Pupin to serve as Serbian representative at the Paris peace conference in April, 1919. Here, in collaboration with his colleague, Professor Douglas Johnson, he was able to advance arguments which resulted in extending materially the proposed

boundaries of the newly created Kingdom of the Serbs, Croats and Slovenes, now known as Yugoslavia.

On the entrance of the United States into the World War in 1917, Professor Pupin organized a group at Columbia University for research into methods of detecting submarines. Together with his colleagues, Professors A. P. Wills and J. H. Morecroft, he carried forward many interesting and valuable experiments on submarine detection at Key West, Florida, and New London, Connecticut, making use of supersonic waves. During the war he served as member of the National Research Council and the National Advisory Committee for Aeronautics. After the war he helped munificently to restore the Serbian churches, schools, museums, etc., for which cause he contributed about one hundred thousand dollars over a period of fourteen years.

In 1911 he had established a memorial fund of $25,000 with the Royal Society in Belgrade in memory of his mother, Olympiada Pupin, the income of the fund to be used for scholarships. In 1928 he established a trust fund of ten million dinars (about $250,000). This fund, which is at the disposal of the Serbian Cultural Society of Belgrade, is to be used for scholarships. Just before his death, he established another fund, the Pupin Memorial Fund of two million dinars (about $50,000). Out of this fund a Pupin memorial home was built in his native village of Idvor. In this there are classrooms for students in agriculture, lecture rooms, and a large hall for moving pictures, concerts, etc. The fund provides several annual scholarships for boys of Idvor for advanced study of agriculture. He also gave other sums for cultural purposes to the National Museum in Belgrade and the Museum of Art in Zagreb.

A few years before his death Professor Pupin transferred the remainder of his property to Columbia University, subject, however, to certain life interests. At the expiration of these life interests, the income is to be applied to the support of research in physics and physical chemistry.

For many years Pupin had been in demand as a speaker on public occasions. This demand increased greatly after the publi-

cation of "From Immigrant to Inventor." He was always an interesting and impressive speaker to the layman in science. He did much service in arousing popular interest in science, and especially in combating that strange notion that prevails in some quarters that over-development of science is a potent cause of our economic ills.

In person, Professor Pupin was a large, vigorous man who gave the impression of great reserve of physical strength. He had a vivid personality that impressed all who came in contact with him. He was fond of social life, was of fine breeding and possessed the social graces to a high degree. He was generous and hospitable in social intercourse, and for the last thirty-five years of his life it was his custom to invite his many friends in succession to enjoy visits during the summer at his home in Norfolk.

Pupin's great physical vigor lasted him up to seventy years of his life, when a decline in health began. A partial paralysis of the legs set in which gradually increased, and finally he was not able to walk, but was confined to chair and bed. He died at the Harkness Pavilion at the Medical Center, New York City, on the twelfth day of March, 1935.

Below this sketch is appended a list of his many honors, awards and degrees. A list is also given of his published papers and of his patents.

Professor Pupin received many honors and awards for his services to engineering, to science, and to public affairs.

Awards:

The Elliot Cresson Medal of the Franklin Institute.
The Edison Medal of the American Institute of Electrical Engineers.
Honor Medal of the Radio Institute of America.
Honor Medal of the Institute of Social Sciences.
The Herbert Prix of the French Academy.
The John Fritz Medal of the Four National Engineering Societies.

Awards and Decorations:

George Washington Award of the Western Society of Engineers. 1928.
White Eagle, First Order of Yugoslavia. 1929.
White Lion, First Order of Czechoslovakia. 1929.

Membership in Societies:

National Academy of Sciences.
American Mathematical Society.
American Philosophical Society.
American Physical Society.
Honorary Member, American Institute of Electrical Engineers.
Honorary Member, German Electrical Society.
Corresponding Member, Royal Serbian Academy, Belgrade.

President of:

New York Academy of Sciences.
Radio Institute of America.
American Institute of Electrical Engineers.
American Association for the Advancement of Science.
University Club of New York,
also, Chairman of the Engineering Foundation.

Honorary Degrees:

Year	*Degree*	*Institution*
1904	Sc.D.	Columbia University
1915	LL.D.	Johns Hopkins University
1924	Sc.D.	Princeton University
1924	LL.D.	New York University
1924	LL.B.	Muhlenberg College
1925	D.Eng.	Case School of Applied Science
1925	L.H.D.	George Washington University
1925	Sc.D.	Union College
1926	LL.D.	Marietta College
1926	LL.D.	University of California
1926	Sc.D.	Rutgers University
1926	LL.D.	Delaware University
1926	LL.D.	Kenyon College
1927	Sc.D.	Brown University
1927	Sc.D.	Rochester University
1928	LL.D.	Middlebury College
1929	Sc.D.	University of Belgrade, Yugoslavia
1929	Sc.D.	University of Prague, Czechoslovakia

BOOKS BY MICHAEL I. PUPIN

Thermodynamics of Reversible Cycles in Gases and Saturated Vapors. John Wiley & Sons. 1894.

Serbian Orthodox Church, edited by Michael I. Pupin. . . . with an introduction by Sir Thomas Graham Jackson, bart. London, J. Murray. 1918. 64 pp., 64 pl.

Yugoslavia. (In Association for International Conciliation Amer. branch —Yugoslavia). American Association for International Conciliation. 1919.

From Immigrant to Inventor. New York, Scribner. 1923. 396 pp.

The New Reformation; from Physical to Spiritual Realities. New York, Scribner. 1927. 273 pp.

Romance of the Machine. New York, Scribner. 1930. 111 pp.

Discussion by M. Pupin and other prominent engineers in "Toward Civilization," edited by C. A. Beard. New York, Longmans, Green & Co. 1930.

SCIENTIFIC PUBLICATIONS OF M. I. PUPIN

1889

Der Osmotische Druch und seine Beziehung zur Freien Energie. Inaugural Dissertation, Berlin, June, 1889.

1890

Practical Aspects of the Alternating Current Theory, May 21, 1890. Trans. Amer. Inst. Elec. Eng., Vol. vii, 204, June and July, 1890.

1891

On Polyphasal Generators, Dec. 16, 1891. Trans. Amer. Inst. Elec. Eng., Vol. viii, Dec., 1891.

The Characteristic Features of the Frankfurt Electrical Exhibition. School of Mines Quarterly, Nov., 1891.

1892

On the Action of Vacuum Discharge Streamers upon Each Other. Amer. Jour. Sci., April, 1892.

On Electrical Discharges through Poor Vacua and on Coronoidal Discharges. Amer. Jour. Sci., June, 1892.

1893

New Method of Measuring the Solar Corona without an Eclipse. Astron. & Astro Phys., April, 1893.

On Electrical Oscillations of Low Frequency and their Resonance. Amer. Jour. Sci., April, May and June, 1893.

Practical Aspects of Low Frequency Electrical Resonance, May 17, 1893. Trans. Amer. Inst. Elec. Eng., Vol. x, 370, June and July, 1893.

1894

Resonance Analysis of Alternating and Polyphase Currents, May 17, 1894. Amer. Jour. Sci., Nov., 1894. Trans. Amer. Inst. Elec. Eng., Vol. xi, Oct., 1894.

Submarine Rapid Telegraphy and Telephony. Elec. World, May 19, 1894.

System of Resonating Conductors for Telegraphy and Telephony. Elec. Eng., May, 1894.

1895

An Automatic Mercury Vapor Pump. Amer. Jour. Sci., January, 1895.

The Most General Relation Between Electric and Magnetic Force and their Respective Displacements. A.A.A.S. Proc., 1895; 55-56.

Electrical Consonance. Elec. World, Feb. 9, 1895.

"Les Oscillations Electriques," by H. Poincare (Review), Science, Jan. and Feb., 1895.

Studies in the Electro-Magnetic Theory. I. The Law of Electro-Magnetic Flux. Amer. Jour. Sci., Series 4, Vol. 1, 1895.

Tendencies of Modern Electrical Research. Address delivered before the New York Academy of Sciences, April 28, 1895. Science, Vol. ii, No. 52, Dec., 1895.

1896

Roentgen Rays. Science, 1896.

Diffuse Reflection of Roentgen Rays (Science, April, 1896), announcing Pupin's discovery of secondary X-ray radiation.

1899

Propagation of Long Electrical Waves, Mar. 22, 1899. Trans. Amer. Inst. Elec. Eng., Vol. xv, 144.

Magnetizing Iron with Alternating Currents, Preliminary Account. (1899.) N. Y. Acad. Sc. Annals 1899-1900, 658.

1900

Wave Transmission over Non-Uniform Cables and Long-Distance Airlines. Trans. Amer. Inst. Elec. Eng., Vol. xvii, May 18, 1900.

Wave Propagation over Non-Uniform Electrical Conductors. Trans. Amer. Math. Soc., July, 1900.

Electrolytic Rectifier of Alternating Currents. Bull. Amer. Phys. Soc., Vol. i, 20.

A Faradmeter. Trans. Amer. Inst. Elec. Eng., Vol. xvii, 75-77, 1900.

Wave Propagation Over Bridged Wave Conductors. (1900). Amer. Math. Soc. Bul., 1901; 7, 202, 205-206.

1901

Transatlantic Communication by Means of the Telephone. Eng. Mag., Vol. 21, 105-14. April, 1901.

A Note on Loaded Conductors. Elec. World and Eng., Vol. 38, 587-588, Oct. 12, 1901.

1902

The General Problem of Wave Propagation over Non-Uniform Conductors. Elec. World and Eng., Mar. 1, 1902.

1907

Distortion in Telephone Transmission. Elec. World, Vol. 50, 927, Nov. 9, 1907. (Letters to the editors.)

1915

Aerial Transmission Problems. Science, Dec. 10, 1915. n.s. 42, 809.

1926

Fifty Years' Progress in Electrical Communications. Science, Vol. 64, 631-638, Dec. 31, 1926. Journ. Amer. Inst. Elec. Eng., Vol. 46, 59-61, 171-174, Jan., Feb., 1927.

1931

Balancing Cables for Inductive Networks. Elec. Eng., Vol. 50, 933-936, Dec., 1931. Elec. Communication, Vol. 10, no. 4, 218-22, April, 1932.

1933

Impendance Curves of a Composite Cable. Elec. Eng., Vol. 52, 115-118, Feb., 1933.

1934

The Equation of Electrical Propagation. Elec. Eng., Vol. 53, 691-694. May, 1934.

OTHER PUBLICATIONS BY M. I. PUPIN

1893

Review of Nikola Tesla's Lecture on Light and Other High Frequency Phenomena. Phys. Rev., Nov. and Dec., 1893.

1894

The Faraday-Maxwell-Hertzian Epoch. Elec. World, Feb., March, and April, 1894.

1895

Tendencies of Modern Electrical Research. Science, 1895; n.s. Vol. 2. 861-880.

1901

Electrical Progress During the Last Decade. Cosmopolitan, Vol. 31, 523-5. Sept., 1901.

1915

Servia's Struggle. Amer. Rev. of Rev., Vol. 51, 203-208. Feb., 1915.

1922

A Herdsman's View of Human Life. Colum. Alum. News, Jan. 13, 1922; Vol. XIII, 197-199.

An Immigrant Student at Columbia in 1879. Colum. Alum. News, Dec. 15, 1922; Vol. XIV, 137-140.

1923

America's Position in Physical Sciences. Colum. Alum. News, Feb. 9, 1923; Vol. XIV, 235-237.

The Spiritual Influence of a Noted Scientist. (Henry Marion Howe.) Colum. Alum. News, Nov. 2, 1923; Vol. XV, 66-67.

1924

Science and the Industries. Colum. Alum. News, Mar. 7, 1924, Vol. XV, 314-316.

From Chaos to Cosmos. Scribner's Magazine. Vol. 76, 3-10, July, 1924.

1925

The Meaning of Scientific Research. Science, n.s. Vol. 62, 26-30. Jan. 9, 1925.

Law, Description and Hypothesis in the Electrical Science. Science, n. s. Vol. 62, 17-22. July 1, 1925.

Chandler: the Teacher and the Chemist. Science, n.s. Vol. 62, 499-501, Dec. 4, 1925.

1926

Lincoln's Revelation to a Serbian Immigrant. (Address delivered at Springfield, Illinois, Feb. 12, 1926.) Bull., Lincoln Memorial Association.

The Invisible Service of Science. School and Society, Vol. 23, 230-2. Feb., 1926. Also in Journ. Amer. Inst. Elec. Eng., Vol. 45, 107-8. Feb., 1926.

The New Reformation: the Triumph of Individualism in Science. 1926. Scribner's Magazine, Vol. 79, 113-20, 275-83, Feb.-Mar., 1926.

The Idealism of the American University. (Charter day address at University of California, March 23, 1926.) Univ. Calif. Chronicle, Vol. 28, 311-17, July, 1926.

Cosmic Harness of Moving Electricity. (Presidential address, American Institute of Electrical Engineering, White Sulphur Springs, 1926.) Journ. Amer. Inst. Elec. Eng., Vol. 45, 758-61. August, 1926.

1927

Higher Endeavor in Science. Science, n.s. Vol. 65, 509-11. May 27, 1927.

Creative Coordination; a Message from Physical Science. Scribner's Magazine, Vol. 82, 142-53. August, 1927.
Creative Coordination. School and Society, Vol. 26, 543-7, October 29, 1927.

1928

Our Industrialism and Idealism. Scribner's Magazine, Vol. 83, 659-664. June, 1928.
Unity of Knowledge. Methodist Review, Vol. 111, 169-75. March, 1928.

1929

The Pioneering Professors. Scribner's Magazine, Vol. 85, 123-6. Feb., 1929.

1930

Romance of the Machine. Scribner's Magazine, Vol. 87, 130-7. Feb., 1930.

1931

Man and the Universe. Review of Reviews, Vol. 83, 73-85, March, 1931.
Introductory remarks (at a dinner given in honor of Sir James Hopwood Jeans in New York). Scientific Monthly, Vol. 33, 10-11. July, 1931.

1933

Our Debt to Joseph Henry, Scientist. American Scholar, Vol. 2, 132-8. March, 1933.
A Message from Science. Scribner's Magazine, Vol. 93, 300-3. May, 1933.

LIST OF PATENTS

1894

519,346 Apparatus for telegraphic or telephonic transmission
519,347 Transformer for telegraphic, telephonic, or other electrical systems

1900

640,515 Distributing electrical energy by alternating currents
640,516 Electrical transmission by resonance-circuits
652,230 Reducing attenuation of electrical waves and apparatus thereof
652,231 Reducing attenuation of electrical waves

1902

697,660 Winding-machine
707,007 Multiple telegraphy
707,008 Multiple telegraphy
713,044 Producing asymmetrical currents from symmetrical alternating electromotive forces
713,045 Apparatus for producing asymmetrical currents from symmetrical alternating electromotive forces

1904

761,995 Apparatus for reducing alternation of electrical waves
768,301 Wireless electrical signalling

1906

821,741 Telegraphy

1920

1,334,165 Electric-wave transmission
1,336,378 Antenna with distributed positive resistance

1921

1,388,441 Multiple antenna for electrical wave transmission
1,399,877 Sound generator

1922

1,415,845 Selectively opposing impedance to received electrical oscillations
1,416,061 Radio-receiving system having high selectivity

1923

1,446,769 Aperiodic pilot conductor
1,456,909 Wave conductor
1,452,833 Selective amplifying apparatus

1924

1,488,514 Selective amplifying apparatus
1,494,803 Electrical tuning
1,502,875 Tone-producing radio receiver

1925

1,541,845 Electrical wave transmission
1,561,278 Wave signalling system
1,561,279 Equalizing vacuum-tube amplifier

1926

1,571,488 Electromagnetic production of direct current without fluctuations

1928

1,657,587 Electrical pulse generator

1931

1,834,735 Inductive artificial line
1,811,368 Telegraph system

1934

1,983,774 Supply system for vacuum tubes